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ABSTRACT

Aggregate bank liquid asset holdings (reserves and liquid securities) increased from 13% to 33% of assets from before the Global Financial Crisis (GFC) to 2020. If banks allocate their balance sheet by equalizing the marginal risk-adjusted expected return across asset classes, they hold more liquid assets when they have less advantageous lending opportunities. We show that, indeed, holdings of liquid assets are negatively related to lending opportunities. Our findings indicate that bank liquid asset holdings grew since the GFC because of weak lending opportunities, though regulatory changes help explain the higher liquid asset holdings of the largest banks before COVID.

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1. Introduction

From the quarter before the collapse of Lehman to the last quarter of 2020, bank liquid asset holdings, defined as holdings of cash and securities that are close substitutes for cash, increased from 13% of assets to 33% of assets. Liquid asset holdings play a critical role in the health of the financial system and in the financial strength of individual banks. Although these holdings have no credit risk, they can have interest rate risk. Recently, these liquid assets have been a source of risk for banks because of the increase in interest rates resulting from the tightening of monetary policy since 2022. In contrast to the vast literature on holdings of liquid assets by non-financial firms, the literature on holdings of liquid assets by banks is surprisingly limited and does not seem to have an explanation for the sharp increase in liquid asset holdings of banks since the collapse of Lehman. In this paper, we investigate the determinants of US bank liquid asset holdings from 1984 to 2020 and why these holdings are so high after the Global Financial Crisis (GFC). We show that poor lending opportunities and regulatory changes help explain much of the large increase in liquid assets of banks from the collapse of Lehman to the start of the COVID crisis. The COVID crisis brought about a tsunami of deposits that further increased liquid asset holdings.

Given the importance of liquid assets for banks and the financial system, the lack of evidence on the determinants of bank liquid asset holdings is surprising. This neglect is even more surprising given the magnitude of these holdings, their variation over time, and their variation across banks. At the end of our sample period, banks with assets of $10 billion or more have aggregate liquid assets that exceed $5 trillion; in comparison, non-financial firms with assets of $10 billion or more have aggregate liquid assets of less than $2 trillion in total. From 1984 to 2006, the ratio of aggregate liquid assets to assets falls by 30% for banks with assets of $10 billion or more in 2018 dollars, but then it increases by 28% from 2009 to 2019. As evidence of variation in the liquid assets to assets ratio (LAR) across banks, in our panel of observations from 1984 to 2006, the 25th percentile of the LAR for banks with assets in excess of $10 billion in 2018 dollars is 15.8% and the 75th percentile is 26.3%. Before 2012, large banks (assets greater than $50 billion in 2018 dollars) have a lower LAR than small banks (assets between $2 billion and $10 billion in 2018 dollars), but after 2012 large banks have a much larger LAR than small banks. At the end of our sample period, the average LAR of banks with assets in excess of $250 billion is 40.3%, almost twice the LAR of small banks, which is 20.9%.

There is a large literature on the determinants of liquid asset holdings of non-financial firms that emphasizes the importance of the precautionary motive (for a survey, see Almeida, Campello, Cunha, and Weisbach, 2014), but the variables in the corporate finance literature that are useful to predict liquid asset holdings of non-financial firms are not helpful to predict liquid asset holdings of banks. This is because banks differ from non-financial firms and have potentially unique motives to hold liquid assets. There are five key differences between banks and non-financial firms that are relevant:

1) Banks are in the business of raising funds through deposits and investing them in financial assets (see DeAngelo and Stulz, 2015, for references). They earn a return through the spread between the rate at which they invest and the rate they pay on deposits. The literature generally takes the view that banks have market power in setting deposit rates (e.g., Drechsler, Savov, and Schnabl, 2017; Whited, Wu, and Xiao, 2021), so that deposit rates are typically below the Federal Funds rate, especially when rates are high. Banks can invest the funds available to them in a variety of assets, such as loans, trading assets, liquid assets, and less liquid securities. Everything else equal, we would expect banks to invest across asset classes so that the marginal risk-adjusted expected return is equalized taking into account that the demand for loans is inelastic while the supply of securities is highly elastic (Klein, 1971). Unless liquid assets are dominated assets, a bank will hold liquid assets for portfolio investment reasons. We call this the portfolio investment motive for holding liquid assets. With this motive, a bank is likely to hold more liquid assets when the demand for loans is lower.
2) Whereas non-financial firms tend to match the maturity of their liabilities to the maturity of their assets, financial firms do not proceed that way. Banks engage in liquidity and maturity transformation (see Berger and Bouwman, 2015, for a review of the literature and a measure of liquidity transformation). A large fraction of banks' liabilities is redeemable on demand, so that they have runnable liabilities (Diamond and Dybvig, 1983) or, if they are not redeemable on

demand, have short maturities. In contrast, a substantial fraction of banks' assets are illiquid and have longer maturities. Therefore, banks have a precautionary motive to hold liquid assets that arises from the liquidity and maturity mismatch between their assets and liabilities (see Diamond and Kashyap, 2016, for references). Though non-financial firms may increase liquid asset holdings when their funding is vulnerable, runs on their liabilities are highly unusual. The typical non-financial firm holds liquid assets to cope with revenue shortfalls.

3) Banks often have large contingent liabilities that are not on their balance sheets. For instance, banks enter contracts with firms in the form of credit lines. If these credit lines are drawn down, banks must have cash available to honor their contracts (see Acharya and Mora, 2015). Relatedly, derivatives and other types of contingent liabilities may require the posting of collateral, which takes the form of liquid assets.

4) Banks, especially the largest ones, play a critical role in the payment system. To perform that function, they hold reserves (Copeland, Duffie, and Yang, 2022). Reserves are a component of liquid assets, but the total amount of reserves banks hold is controlled by the Federal Reserve. To the extent that reserves and liquid securities are close substitutes, an increase in reserves should have little impact on holdings of liquid assets. However, if liquid securities are poor substitutes for reserves, an increase in reserves could increase holdings of liquid assets.

5) Banks are highly regulated compared to non-financial firms. Though banks had no liquidity requirements before the GFC, such requirements were introduced afterwards for large banks. We would expect the changes in capital and liquidity regulations after the GFC to have an impact on bank holdings of liquid assets (see Cecchetti and Kashyap, 2016, for how capital and liquidity requirements interact).

For banks to have a portfolio investment motive to hold liquid assets, liquid asset holdings must improve the expected performance of their portfolio of invested assets. A bank with limited opportunities to make profitable loans but with a large deposit franchise has funds to invest, and it will generally invest some of these funds in liquid assets.

The portfolio investment view of liquid asset holdings implies that liquid asset holdings and loans are substitutes. If a bank's lending opportunities improve, it will hold fewer liquid assets. We find that banks with better lending opportunities have lower liquid asset holdings across different panel regression specifications, different subsamples, different subperiods, and different estimation approaches. When we proxy the change in lending opportunities with the change in loans, we show that the relation is robust when we instrument the change in loans using a Bartik-like instrument (Bartik, 1991). With our framework, we expect that banks with good lending opportunities that experience an increase in deposits will use the additional resources to lend more even though they have low liquid asset holdings. In contrast, banks with poorer lending opportunities, and hence more liquid assets, that experience an increase in deposits will invest relatively more of the new funds in liquid assets. We corroborate this conjecture in panel regressions that include an interaction term of instrumented deposits with an indicator variable for banks with low liquid asset holdings.

With the portfolio investment view of liquid asset holdings, we expect these holdings to grow more when banks have weaker lending opportunities and when they have faster deposit growth. Strikingly, while the aggregate growth rates of loans and of deposits are very similar until the GFC, they diverge after the collapse of Lehman so that for the last ten years of our sample period the growth rate of aggregate loans is half the growth rate of aggregate deposits. We use time-series models estimated over the whole sample period to show that our approach helps explain the increase in the aggregate LAR as well as the growth of aggregate liquid assets since the collapse of Lehman. Specifically, a time-series model of the aggregate LAR that incorporates the portfolio investment motive explains the large increase in the aggregate LAR after the collapse of Lehman. Remarkably, if we use the average growth rate in loans for the ten years before the GFC instead of the actual growth rate since the collapse of Lehman, the aggregate LAR would have increased by 4.4% instead of the actual increase of 20.8% or the fitted value of our model of 12.7%. We also find that a time-series model of the growth rate of aggregate holdings of liquid assets tracks this growth well. The time-series model for the aggregate LAR underestimates the increase in LAR after 2012 and especially so during COVID. The underestimate during COVID is not surprising as there was a tsunami of deposits not accompanied by an equivalent increase in lending opportunities.

We investigate in more detail why our time-series models underestimate the increase in liquid assets in the years after 2012. After 2012, the liquid asset holdings of large banks and the other banks evolve quite differently. While the LAR of the largest banks keeps increasing, the LAR of the other banks falls. The most logical candidate for an explanation of this divergence in the holdings of liquid assets between small and large banks in the 2010s is the plethora of regulatory changes that take place after the GFC. These regulatory changes involve an increase in capital requirements that advantages holdings of liquid assets at the expense of loans and the introduction of liquidity requirements that mainly affected large banks.

Using a difference-in-differences design, we find evidence that banks with assets in excess of $50 billion and especially those with assets in excess of $250 billion have higher liquid asset holdings starting with the end of 2013. Such an increase could be consistent with an impact of the introduction of the liquidity coverage ratio, the LCR, which is the main new quantitative liquidity regulation during our sample period, but it could also result from increases in capital requirements. To distinguish between the effect of the LCR and of capital requirements, we use a triple interaction to investigate whether the liquid asset holdings change more for treated banks that have low liquid asset holdings before treatment. We find that this is so for the largest banks. However, when we investigate whether liquid assets increase more for banks with low Tier 1 ratios, we also find that the largest banks with low Tier 1 ratios increase liquid asset holdings more. Banks with low Tier 1 ratios can satisfy the higher risk-based capital requirements by reducing their holdings of risky assets and replacing them with liquid asset holdings. Consequently, our results indicate that both the LCR and the change in capital requirements help explain the increase in liquid asset holdings of large banks relative to the other banks after 2012.

The Federal Reserve controls the aggregate amount of reserves and the rate that they earn. Though aggregate reserves are under the control of the Federal Reserve, the liquid asset holdings of individual banks are not directly under the control of the central bank. Our approach is based on the notion that banks choose the amount of liquid assets they want to hold. We also find support for the portfolio investment motive if we consider only non-reserve liquid assets. Specifically, we find that banks hold fewer liquid assets when they have better lending opportunities if we consider only non-reserve liquid assets. We further find little evidence that the interest on reserves that the Fed started paying after the GFC was a major driver of the increase in bank liquid assets holdings.

The paper is organized as follows. In Section 2, we relate our paper to the existing literature. In Section 3, we define bank liquid assets and show how they evolve over time. In Section 4, we develop a conceptual framework for holdings of liquid assets by banks. In Section 5, we provide evidence supportive of our framework using panel regressions. In Section 6, we show that our framework helps explain the high growth of aggregate liquid asset holdings for banks after the GFC and then examine why the liquid asset holdings of the largest banks increase so much relative to the holdings of small banks. We explore the robustness of our findings to alternative definitions of liquid assets in Section 7. We conclude in Section 8.

2. Existing literature

This paper relates to several strands of the banking literature and the literature on crises and the stability of the financial system. In this section, we briefly discuss how the paper relates to the literature.

Following Diamond and Dybvig (1983), there is an enormous literature that focuses on the risk of depositor runs and bank stability. Banks hold liquid assets to cope with deposit withdrawals (see Diamond and Kashyap, 2016). With this literature, there is a liquidity risk management motive for holding liquid assets but no portfolio investment motive. The bank holdings of liquid assets may be too low as banks do not internalize the systemic benefits of their risk management. As a result, there is a growing literature focused on the optimality and design of liquidity requirements (see Allen, 2018, for a review).

Klein (1971) develops a model of bank asset holdings. His model has cash, government bonds, and loans. The demand for loans is downward-sloping, so that holdings of loans are determined by the level of loans where the marginal revenue on loans equals the rate of return on bonds. We build on this model in Section 4. Acharya, Shin, and Yorulmazer (2010) develop a model where banks hold liquid assets because these assets enable them to benefit from fire sales during a crisis. In this paper, the strategic considerations emphasized by Acharya et al. (2010) are part of the portfolio investment motive for holding liquid assets. Diamond and Rajan (2011) have a related paper that has healthy banks hoarding liquid assets to take advantage of fire sales. In that paper, the hoarding of liquid assets comes at the expense of loans, so that banks cut back on lending when liquid assets are especially valuable because they can be used to pay for assets bought in fire sales. Kashyap, Rajan, and Stein (2002) focus on the precautionary motive to hold liquid assets and show that banks can economize on their holdings of liquid assets by using liquid assets to back activities that have imperfectly correlated demands for liquidity, such as deposit withdrawals and takedowns of lines of credit. Our focus is on the holdings of liquid assets that exceed holdings of liquid assets for the precautionary motive.

Bank holdings of liquid assets play an important role in the transmission of monetary policy. Kashyap and Stein (2000) show that monetary policy affects lending much more for banks with low securities holdings. Their results hinge on the substitutability of loans and securities on a bank's balance sheet. They argue that a tightening of monetary policy that reduces a bank's deposits has less of an impact on loans for banks that have plenty of liquid assets as these banks can substitute funding loans with deposits by funding loans with sales of securities. More recently, Bianchi and Bigio (2022) develop a model of bank liquidity management with an over-the-counter interbank market to study the credit channel of monetary policy. Their model centers around the tradeoff between profiting from lending and incurring greater liquidity risk arising from deposit withdrawals. Holding liquid assets reduces the liquidity risk but at the cost of paying a liquidity premium (Nagel, 2016). The central bank can affect the amount of loans by changing the liquidity premium and hence holdings of liquid assets. Though we leave to future research the examination of how monetary policy affects liquid asset holdings of banks, we find little evidence of a relation between the Fed funds rate, a proxy for the liquidity premium (Nagel, 2016), and holdings of liquid assets.

Another related literature focuses on bank liquidity creation. Banks create liquidity by issuing liquid liabilities that they invest in illiquid assets. The seminal empirical paper in that literature is Berger and Bouwman (2009). They divide assets into three categories: illiquid assets, semiliquid assets, and liquid assets. The liquid assets include cash, securities, and trading assets. They then measure the liquidity of a bank's assets and of its liabilities. The difference in liquidity between the liabilities and assets of a bank is their measure of a bank's liquidity creation. Bai, Krishnamurthy, and Weymuller (2018) develop a dynamic measure of asset and liability liquidity that uses market values instead of book values. Our paper focuses on liquid asset holdings. Two banks with the same amount of liquidity creation or the same liquidity mismatch can have very different holdings of liquid assets. Our research helps better understand the determinants of the amount of liquidity creation by banks.

Berger, Guedhami, Kim, and Li (2022) develop what they call measures of liquidity hoarding for the asset side of a bank's balance sheet, the liability side of the balance sheet, and for items that are off-balance sheet. For the asset side, their measure is the ratio of half a bank's liquid assets minus half a bank's illiquid assets. The asset side measure includes liquid assets, but the asset side liquidity measure can change even if liquid assets are constant, so that it is not a measure of liquid assets alone. Hoarding of liquidity implies that banks are refraining from performing liquidity transformation, while in our approach banks hold liquid assets because they lack profitable lending opportunities.

There is a growing literature on the effect of the post-GFC policy and regulatory changes on bank policies. Some papers focus on the channels through which quantitative easing affects the economy. Acharya and Rajan (2022) develop a model showing that central bank balance sheet expansion can exacerbate episodes of stress because banks finance reserves through runnable liabilities. Diamond, Jiang, and Ma (2021) examine how quantitative easing increases the cost of loans by forcing banks to hold more reserves within a structural model. Their focus is on how the mechanism they develop impacts the effect of quantitative easing on the economy. Their mechanism hinges on a substitution effect between reserves and loans. In our paper, there need not be such a substitution as banks could increase reserves but decrease their holdings of other liquid assets. Darmouni and Rodnyansky (2017) find that quantitative easing increases loans more for banks that hold more mortgage-backed securities. Chakraborty, Goldstein, and McKinlay (2020) show that quantitative easing changes the composition of lending, so that banks with more mortgage lending that can be securitized increase that lending at the expense of C&I lending.

Other papers study the effects of the LCR. Cetina and Gleason (2015) show how difficult it is to figure out exactly the quantity of liquid assets a bank has to hold to meet the LCR requirement. Roberts, Sarkar, and Shachar (2019) find that the LCR decreases bank liquidity creation and that it does so in part through a decrease in lending. Bosshardt and Kakhbod (2020) conclude that the LCR increases the non-performing loans ratio of banks as well as the liquid assets ratio. Their definition of liquid assets is much broader than ours, since they include relatively illiquid securities that are penalized with the LCR. Ihrig, Kim, Vojtech, and Weinbach (2019) show that high-quality liquid assets held by banks are mostly reserves, US Treasuries, and GSE MBS. Whited, Wu, and Xiao (2021) examine the impact of low interest rates on bank risk-taking in a structural model. They have substitution between loans and liquid assets, but their balance sheet assumptions do not include credit-risky and illiquid securities. While we focus on bank holdings of liquid assets, they focus on the impact of low rates and liquidity requirements on bank values.

3. Bank liquid assets: Definition and evolution over time

Liquid assets are assets that can be sold rapidly with little or no price pressure (Grossman and Miller, 1988). We obtain the data for liquid assets from the Reports of Conditions and Income (Call Reports).[1] Our measure of liquid assets includes bank cash holdings, US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. We define bank cash holdings as vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. All the assets we include in the definition trade in liquid markets, have little or no credit risk, and can easily be used for repurchase agreements. In Section 7, we discuss how our results hold for different definitions of liquid assets and different samples.

We compute the liquid asset holdings from March 1984 to December 2020 for all US-chartered commercial banks (charter type 200) with assets in excess of $2 billion. We drop banks with missing data

[1] We obtain call report data using a modified code from Drechsler, Savov, and Schnabl (2017) and follow Drechsler et al. (2017) to form consistent time-series data.

on assets and those with a negative book value of equity. In the following, all dollar amounts are in constant 2018 dollars (using the CPI deflator), except for those amounts set by regulations. We have 1,282 unique banks. At times, we divide banks between large, medium, and small banks. We define large banks to be banks with assets in excess of $50 billion dollars. Medium banks have assets between $10 billion and $50 billion. Small banks have assets between $2 billion and $10 billion. Small and medium banks form the category of "other banks." We have 324 banks in 1984. The lowest number of banks is 288 in 2010. In 2020, we have 405 banks.

Figure 1 shows the evolution of the aggregate LAR. The aggregate LAR is computed by summing liquid assets for all banks in the sample and dividing them by the sum of assets for all banks. Aggregate LAR hovers around 20% until the early 1990s, when it increases to a pre-GFC peak of 24% in December 1992. After the pre-GFC peak, it falls to reach a trough of 12.4% in the first quarter of 2008. After that trough, the aggregate LAR doubles to reach 25.4% in December 2019 before the COVID crisis and 33.2% at the end of our sample period. We show in the same figure the percentage of assets represented by loans. The aggregate loans-to-assets ratio is computed by summing loans across banks and dividing them by the sum of assets. The fraction of the balance sheet of the banking sector corresponding to loans falls for most of our sample period, but it increases slightly between 2015 and 2019 before falling again in 2020. The peak aggregate loans-to-assets ratio before the GFC is 65%. The trough aggregate loans-to-assets ratio is 47.3% at the end of the sample. Before the COVID crisis, the trough of aggregate loans-to-assets is 49.4% in the third quarter of 2011. The figure suggests an inverse time-series association between the aggregate loan ratio and the aggregate LAR over time, which is what one would expect if loans and liquid assets are substitutes.

For banks, liquid assets are the sum of cash and non-cash liquid assets. We show the evolution of the components of liquid assets in Figure 1. We compute the aggregate cash-to-assets ratio, which is the sum of cash holdings of sample banks scaled by the sum of assets of sample banks. These cash holdings include reserves held at the Federal Reserve. Before the GFC, reserves held at the Federal Reserve pay no interest. Shortly after the collapse of Lehman, on October 9, 2008, the Federal Reserve starts paying interest on excess reserves of 75 basis points. The interest rate stays positive but varies over time during the remainder of our sample period. The aggregate cash-to-assets ratio falls dramatically from 16% in 1984 to a low of 4.1% in 2006. After staying between 4.1% and 4.7% from 2006 to the second quarter of 2008, it then increases sharply, starting with the bankruptcy of Lehman, before eventually dropping before the COVID crisis. At the end of 2019, this ratio is the lowest since the first quarter of 2011. At the end of our sample period, the ratio stands at 15.2%.

Early in the sample period, the aggregate cash-to-assets ratio exceeds the aggregate non-cash liquid assets-to-assets ratio. The non-cash liquid assets-to-assets ratio is 5.9% at the beginning of the sample period. It increases steadily and eventually exceeds the cash-to-assets ratio in 1991 as the cash liquid assets-to-assets ratio falls. Once the non-cash liquid assets-to-assets ratio exceeds the cash-to-assets ratio, it does so every year except in the last two quarters of 2013, 2014, and the first quarter of 2015. After the GFC, the ratio of non-cash liquid assets-to-assets ratio increases steadily, while the ratio of cash-to-assets increases at first and then falls. Just before the COVID crisis, at the end of 2019, the non-cash liquid assets-to-assets ratio peaks at 16.2%, which is almost three times the level of the ratio at the beginning of the sample period.

In Figure 2, we show results for equally-weighted averages of the LAR for small, medium, and large banks. Before the GFC, the LAR for small and medium banks always exceeds the LAR of large banks. In the 2000s, before the GFC, the LAR falls for all three groups of banks, but more so for small banks. In the last quarter of 1999, the LAR is 23.2% for small banks and 16.7% for large banks. From the end of 1999 to the middle of 2008, the LAR of small banks falls by 8.2 percentage points and the LAR of large banks falls by 3.3 percentage points. During the GFC, the LAR initially falls for all three groups of banks and then rebounds sharply. The increase in the LAR following the trough in 2008 is the largest for the large banks, so their LAR increases to match the LAR of medium and small banks in 2009. By 2013, the LAR of large banks exceeds the LAR of small and medium banks. It stays that way until the end of the sample period. In the last quarter of our sample period, the LAR of large banks exceeds the LAR of small banks by 10.7 percentage points.

4. Why do banks hold liquid assets?

In this section, we first discuss the role of the transaction and precautionary motives for bank liquid asset holdings. We next introduce the portfolio investment motive. We then discuss the role of regulation and reserves. We conclude with a summary of empirical predictions that we examine in the remainder of the paper.

4.1. The precautionary and transaction motives

Non-financial firms are typically not in the business of raising funds to invest them in financial assets for the purpose of getting income from such assets. They generally want to finance and grow their business activities. As a result, they tend to be highly concerned about the risk of cash flow shocks (e.g., Smith and Stulz, 1985; Froot, Scharfstein, and Stein, 1993). The literature relates holdings of liquid assets to firm characteristics that proxy for the precautionary motive. We show in the Internet Appendix that these variables are not helpful in explaining bank holdings of liquid assets. In contrast to non-financial firms, banks create shareholder wealth through their liabilities. In particular, a bank's deposit franchise can be highly valuable. Banks raise deposits at an average cost that is less than their cost of funding if they had to raise funding from financial markets.

Banks face the risk of having to deliver cash to counterparties that have claims that are redeemable on sight. Banks' demand deposits have that property, but banks also have other claims with that property (Duffie, 2010). Further, banks have claims with short maturities, as they often borrow overnight or at very short maturities. If its short-term liabilities do not roll over, a bank may have to default. In addition, banks have commitments that may be exercisable on sight or on short notice. These commitments include credit lines and derivatives contracts. To protect themselves against claimants redeeming their claims or against the possibility of not being able to rollover short-term claims, banks hold liquid assets for precautionary reasons.

From the literature, the main concern that precautionary holdings of liquid assets address is the risk of a run on the bank's liabilities. Everything else equal, we would expect the risk of such a run to be lower if a bank has more liquid assets. With this view, we would expect liquid assets to be higher if the bank has more demand deposits. In general, however, deposit accounts are insured directly up to some amount, and the excess over that amount is viewed as insured implicitly at least to some extent. Banks have other runnable or short maturity liabilities, on and off their balance sheets, that do not benefit from implicit government insurance. The risk of loss on such liabilities is less of a concern if the bank holds more equity. We would therefore expect that banks with more equity, everything else equal, require lower precautionary holdings of liquid assets. Given a bank's leverage, we would expect a bank with more loans to require more precautionary holdings of liquid assets as it is more likely to experience losses that could reduce its equity buffer and lead to a run on its deposits. Banks with more commitments, such as non-drawn credit lines, are expected to hold more liquid assets because they have to be able to honor these commitments. We would therefore expect liquid assets to increase with commitments and derivatives.

Banks also hold liquid assets for the transaction motive. Holders of deposit accounts use them for transactions, and the bank has to be in a position to honor the payments they make through their accounts. These payments affect the liquidity position of banks (Li, Li, and Sun, 2021). The best liquid asset for the transaction motive is cash, which generally means reserves held at the Federal Reserve. Reserves are also the liquid asset that is most easily usable if the bank has an unexpected demand for payment. The largest banks have a large demand for reserves to manage intra-day flows (Copeland et al., 2022). We, therefore, expect that the precautionary and transaction motives involve holdings of cash first. Other liquid assets have to be converted into cash, so that they do not have proceeds that are instantly usable.

4.2. The portfolio investment motive

In general, banks can allocate the proceeds from deposits to loans, cash, and securities. There is much evidence in the literature that banks face a downward-sloping demand for loans. For instance, Degryse and Ongena (2005) show that banks charge less for loans to firms that are farther away from them, which is consistent with an inelastic demand for loans that enables banks to price discriminate. Therefore, we assume, as is frequently done since Klein (1971), that banks have a downward-sloping demand for loans.

The demand for loans varies across banks and over time. When the demand is high, the average profitability of loans is greater and a bank underwrites more loans. However, even then, a bank may have a surplus of investable funds. A bank can invest these funds in liquid securities, illiquid securities, and trading assets. Consequently, a bank may have a portfolio motive to hold liquid assets. Specifically, the bank may allocate part of its portfolio of financial assets to liquid assets because it is advantageous for it to do so from the perspective of investing that portfolio optimally. In other words, liquid assets may offer a risk-return profile that is attractive for the bank's overall portfolio. These assets may be attractive because of their diversification benefit, because of the flexibility they provide, and because of the low cost of monitoring a portfolio of liquid assets. When facing a low demand for loans, the bank could shrink its balance sheet. This would make sense for the bank if its marginal cost of funding were persistently higher than the marginal expected return on the funds it invests. In general, banks will earn more than the marginal cost of deposits on liquid assets up to some level of deposits. A bank will, therefore, optimally choose to issue deposits up to that level. Further, even if the marginal expected return on the funds it invests were particularly low at a given time, the bank might not want to chase away deposits as it might benefit from them when the marginal expected return on the funds it invests increases, for instance because of an increase in the demand for loans.

To analyze the determinants of the portfolio investment motive, it is useful to think about a risk-neutral bank with a balance sheet that has loans, liquid assets, deposits, and equity. For simplicity, we first ignore the precautionary motive for holding liquid assets. Let's assume that deposits, D, and equity, E, are fixed. The assets are funded at a cost of r per dollar. The bank can invest in liquid assets. These investments have an expected return of r^*. The supply of liquid assets to the bank is perfectly elastic, so that there is a constant expected marginal revenue curve for investment in liquid assets at r^*, as shown in Panel A of Figure 3. If $r^* > r$, the bank could be profitable by just investing in liquid assets. Consider now the demand for loans the bank faces. Let L be the amount of loans the bank makes. We assume that the demand for loans decreases as a function of the expected return on loans, r_L, so that we write $L(r_L)$. The expected return on loans is the rate the borrower promises to pay minus the expected credit losses and minus the expected cost of making and managing the loan. As a result, the demand for loans is downward-sloping as shown in Figure 3. With a downward-sloping demand curve, the marginal revenue curve, $L'(r_L)$, is downward-sloping as well. The bank will set the amount of loans, L, at the point where the expected marginal revenue from loans equals the expected marginal revenue from investing in liquid assets provided that $L < D + E$. In that case, the bank will not invest all its internal funds in loans. Instead, it will invest some in liquid assets. In contrast, if the loan demand is high, then $L = D + E$, and the bank will be better off not investing in liquid assets. It follows that a decrease in the demand for loans that moves the demand curve to the left causes the bank to invest more in liquid assets. Similarly, an increase in the expected return on liquid assets causes a decrease in the quantity of loans made by the bank.

The model discussed in the previous paragraph has the key implication of our theory of the determinants of liquid asset holdings: banks will hold liquid assets for the portfolio investment motive as long as the demand for their loans is not so large that loans always dominate liquid assets as investments for the bank. In the model above, we ignore deadweight costs of financial distress. In general, however, sufficiently adverse outcomes have deadweight costs. With deadweight costs of adverse outcomes, the bank wants to manage its risk. In this case, the precautionary motive provides another reason to invest in liquid assets.

As discussed, banks have transaction and precautionary motives to hold liquid assets. Hence, there is an optimal amount of liquid assets held for these motives. One way to introduce these motives in our simple model is to include in the expected return from liquid assets the benefits these assets give the bank to facilitate transactions and reduce risk. With this approach, the marginal expected return on liquid assets decreases as the amount of liquid assets increases because each additional dollar of liquid assets has a lower benefit for the transaction and precautionary motives. If, at some point, an additional dollar of liquid assets has no benefit for the transaction and precautionary motives, then the expected net return on liquid assets is r^*. If the intersection of the marginal revenue curve from loans is on the flat part of the marginal revenue curve from liquid assets, then the quantity of liquid assets does not depend on the transaction and precautionary motives. Panel B of Figure 3 shows this case.

If the portfolio motive is sufficiently strong, the marginal dollar of liquid assets is held for the portfolio motive, not the transaction and precautionary motives. In this case, to a first-order approximation, the amount of liquid assets held by the bank fluctuates because of changes in the portfolio motive rather than because of changes in the transaction and precautionary motives. The key prediction implied by our framework is that holdings of liquid assets are higher when the demand for loans is lower as long as the marginal revenue curve of loans intersects with the marginal revenue curve from investing in liquid assets so that $L < D + E$. This prediction implies that an increase in the demand for loans causes a decrease in holdings of liquid assets. We investigate this prediction in Section 5.

Now suppose that the demand for deposits increases so that the bank can have a larger amount of deposits for the same rates, everything else equal. In this case, the bank's assets would increase. The loan amount would be unchanged because the demand for loans is unchanged. As a result, the increase in the demand for deposits would result in an increase in holdings of liquid assets. We show this in Panel C of Figure 3. With this figure, if the marginal revenue curve for loans were to intersect the marginal revenue curve of investing in liquid assets on its upward-sloping part, an increase in deposits would increase loans. Hence, for a bank with strong lending opportunities, an increase in deposits causes an increase in loans. We investigate these predictions in Section 5 as well.

4.3. Reserves and liquid asset holdings

The marginal reserve requirement for our sample period is 10% of net transaction accounts until March 2020 when it goes to zero. As discussed in Bennett and Peristiani (2002), reserve requirements become less important over time because banks use sweep accounts to reduce the size of net transaction accounts. Starting with the GFC, the Federal Reserve expands its balance sheet massively, so that it creates excess reserves that the banking system has to hold. The expansion of the Federal Reserve balance sheet raises the question of how the creation of excess reserves affects bank holdings of liquid assets. At the bank level, the aggregate amount of reserves is not relevant as a bank chooses its amount of excess reserves. An individual bank can choose the composition of its liquid assets as it pleases as long as it satisfies regulatory requirements (the reserve and capital requirements throughout the sample period and the liquidity requirements after the GFC). However, prices have to adjust so that reserves as a whole are held by the banks. Before the GFC, since reserves do not pay interest, banks attempt to minimize reserves. The situation is more complicated after the GFC. When reserves pay interest, banks' willingness to hold excess reserves increases with the interest rate they pay. To address the concern that aggregate reserves are determined by the Federal Reserve, we repeat our analyses of the determinants of bank liquid assets for non-reserve liquid assets.

4.4. Regulation and bank liquid asset holdings

Banks are subject to capital requirements and liquidity requirements. We consider these requirements in turn. Starting with capital requirements, it is important to note that banks would be subject to capital requirements by the market even if there were no requirements from the official sector. If a bank has too little capital, it will not be able to find counterparties and will fail. As a result, the bank has to satisfy a minimum capital requirement, which is the highest among the regulatory capital requirements and the market capital requirement. For simplicity, suppose that this minimum capital requirement can be formalized as the requirement that the equity-to-assets ratio is higher or equal to x. If the bank has an equity-to-assets ratio equal to y, which is higher than x, we say that the bank is not constrained by capital. An unconstrained bank can expand its balance sheet without raising equity. A constrained bank has $y = x$, and it cannot expand the balance sheet without raising equity. We distinguish between constrained and unconstrained banks. For simplicity, we assume that raising capital is not possible in the short run. This reflects the well-known reluctance or difficulty that banks have in raising equity.

Suppose that a bank requires more capital to support a dollar of loans than a dollar of liquid assets. Such an outcome holds with the risk-based capital requirement. In this case, a constrained bank can become unconstrained by replacing loans with liquid assets. Consequently, capital requirements affect a bank's optimal holdings of liquid assets. However, if the binding capital requirement for a bank is the leverage ratio, which is a capital requirement that depends on the size of the balance sheet rather than the composition of the bank's assets, then replacing loans with liquid assets will not enable the bank to become unconstrained. An unconstrained bank can make decisions on the allocation of assets without being constrained by capital requirements as long as it remains unconstrained. A bank that is unconstrained can become constrained because of an increase in capital requirements. Capital requirements increase substantially after the GFC (Walter, 2019). With our framework, one way that a bank can at least partly accommodate an increase in risk-based capital requirements is by replacing loans with liquid assets. It follows from this that a bank that targets its capital ratios so that it has a margin of safety over the regulatory and market required ratios will typically hold more capital if it has more loans, as loans are more capital intensive than liquid assets. Hence, the capital requirements induce a negative relation between equity and holdings of liquid assets.

We turn now to the liquidity regulations. The US did not have such regulations before the GFC. After the GFC, it eventually implemented new liquidity regulations that were finalized in 2014. Consider a regulation that requires a bank to have liquid asset holdings such that the LAR has to be equal to or greater than k. Suppose that the same bank wants to have liquid assets of m as a fraction of assets for the precautionary motive. These liquid assets have to be in excess of k as the bank cannot use the liquid assets held for regulatory reasons.[2] Consequently, the bank wants a LAR at least equal to $k + m$. Before the implementation of the regulation, the bank has LAR > m, so that the marginal dollar is not held for the transaction and precautionary motives. If the new regulation is such that LAR > $m + k$, the bank can keep holding its liquid assets and does not need to change anything. However, suppose that LAR < $m + k$. In this case, the bank does not have enough liquid assets. The bank can shrink its balance sheet or it can acquire liquid assets. In particular, the bank could build its holdings of liquid assets by decreasing the size of its loan book through loan sales or through loan repayments.

[2] In principle, banks could choose to let their liquid assets drop below the LCR when under stress. However, banks seem unwilling to do so as evidence by the events of March 2020 (Nelson and Waxman, 2021; Basel Committee on Banking Supervision, 2022).

Panel D of Figure 3 shows the impact of a liquidity requirement. The liquidity requirement means that some fraction of the balance sheet has to be immobilized in liquid assets. Now, the liquid assets held for the precautionary motive come in addition to the required liquid assets, so that the intersection between the marginal revenue curve for loans and the marginal revenue curve for liquid assets moves from L to L^* and the expected net return on loans increases from r^* to r^{**}. The imposition of a liquidity requirement reduces loans and makes loans more expensive.

4.5. Summing up and hypotheses

Figure 3 summarizes the interaction of the various motives we have discussed in the simplified case where a bank's assets are only loans and liquid assets and where its liabilities are only deposits and equity. The figure neglects many complications. Most importantly, it neglects that banks have assets other than liquid assets and loans and that they have other liabilities besides deposits and equity. However, there is no reason to believe that our main empirical predictions do not hold if we take these complications into account. For instance, we would still expect an increase in the demand for loans to decrease other assets held by banks. Keeping the marginal gain from investing in these other assets constant, we would expect a proportional reduction in their holdings as the demand for loans increases. It follows that, in a model that allows for more types of assets, the key predictions of the portfolio motive are:

1) An increase in the demand for loans causes a decrease in liquid assets. This decrease in liquid assets is smaller for banks with good lending opportunities (that have a low LAR in the first place).
2) If a bank experiences an increase in deposits, everything else equal, liquid assets increase for banks unless a bank has extremely good lending opportunities. As a result, high LAR banks (which tend to have relatively poor lending opportunities in our framework) increase LAR when deposits increase and lending opportunities are unchanged, but low LAR banks (with relatively good lending opportunities in our framework) may not.

3) A liquidity requirement increases liquid asset holdings only if the transaction and precautionary motives to hold liquid assets exceed the holdings of liquid assets in excess of the liquidity requirement before the imposition of the liquidity requirement.

The predictions of the transaction and precautionary motives are that a bank holds more liquid assets for the transaction motive if it has more deposits, especially demand deposits, and holds fewer liquid assets if it has more equity. The latter prediction follows from the fact that a bank with less leverage, everything else the same, is less likely to become distressed. However, it is not clear from the precautionary and transaction motives that a bank holds more liquid assets if it has more deposits since a bank's other sources of non-equity funding may be less predictable than deposits.

5. Are the determinants of bank liquid asset holdings consistent with our framework?

In this section, we investigate whether there is support for the portfolio investment motive for bank holdings of liquid assets. We proceed in three steps. First, we assess the role of the determinants of liquid asset holdings implied by the framework. Second, we consider the relation between liquid asset holdings, deposits, and loans using exogenous variation in deposits and loans through instrumental variables. Third, we test the proposition that low LAR banks are not liquidity-constrained but instead are banks with valuable lending opportunities.

5.1. The determinants of liquid asset holdings

In this section, we first examine regressions of the LAR at time *t* on determinants observed at *t*-1. This approach is similar to an approach used in the literature on liquid asset holdings for non-financial firms (e.g., Opler et al., 1999). In Panel A of Table 1, we regress the LAR at *t* of bank *i* in state *s* on variables that proxy for the transaction, precautionary, and portfolio motives determined at *t*-1. With the portfolio investment motive, banks with better lending opportunities, which translates into a higher ratio of loans-to-assets, have a lower LAR. We regress the LAR on previous quarter log assets, loans-to-assets, demand deposits-to-assets, other deposits-to-assets, equity-to-assets, net income to assets, ROA volatility, and an indicator variable for whether the bank has trading assets:

$$LAR_{ist} = c + \beta_{LA} Log\ Assets_{ist-1} + \beta_{L} Loans/Assets_{ist-1} + \beta_{DD} Demand\ deposits/ Assets_{ist-1} + \beta_{OD} Other\ deposits/Assets_{ist-1} + \beta_{E} Equity/Assets_{ist-1} + \beta_{NE} Net\ income/ Assets_{ist-1} + \beta_{ROA} ROA\ volatility_{ist-4,t-1} + \beta_{TA} Trading\ assets_{ist-1} + \gamma_{st} + \delta_{is} + \varepsilon_{ist} \quad (1)$$

We show the estimates in Panel A of Table 1. The detailed definitions of the variables are given in the Appendix. We estimate regressions for the whole period, the pre-GFC period, and the post-GFC period. Further, we show results for large banks (more than $50 billion of assets) and other banks. The regressions use state-time fixed effects and bank fixed effects. The coefficient on *Loans-to-assets* is negative and roughly similar for the whole sample period and for the two shorter periods. The magnitudes of the coefficients suggest that a decrease of one percentage point in *Loans-to-assets* is associated with an increase in LAR of roughly half a percentage point. The coefficient is negative for small and large banks, but it is not significantly negative for large banks from 1984 to 2006. We then show coefficients for *Demand deposits-to-assets* and *Other deposits-to-assets*. These coefficients are mostly insignificant. Except for large banks before the GFC, the coefficient on *Equity-to-Assets* is significantly negative. This finding is consistent with the precautionary motive.

We estimate additional regressions but report the results only in the Internet Appendix. First, we estimate the regressions using individual loan categories instead of overall loans-to-assets. These categories are C&I loans, real estate loans, and consumer loans. We find that large banks behave quite differently in the pre-GFC period from other banks. Specifically, the coefficient on *C&I loans-to-assets* is not significant for large banks but is significant and three times larger in magnitude for other banks. Second, we re-estimate the regressions adding separately *Other securities-to-assets* and *Non-deposit liabilities-to-assets*. The inferences are similar. *Other securities-to-assets* has significant negative coefficients. Some of the coefficients on *Non-deposit liabilities-to-assets* are positive and significant. Third, we re-estimate the regressions adding *Wholesale funding-to-assets*, *Commitments-to-assets*, and *Derivatives-to-assets*.[3] *Commitments* corresponds to the total unused commitments of the bank. The coefficient on *Commitments-to-assets* is insignificant for the whole sample period and for the pre-GFC period but is significantly positive for the post-GFC period. The coefficient on *Wholesale funding-to-assets* is positive and significant for the pre-GFC period but insignificant otherwise. For *Derivatives*, we use the fair value of derivatives. The coefficient on *Derivatives-to-assets* is insignificant for the whole sample period and for the post-GFC period, but significantly negative for the pre-GFC period. Using an indicator variable for the bank having derivatives instead, we observe a positive and significant coefficient for the post-GFC period, but the coefficient is insignificant otherwise. The addition of these variables does not change our inferences about the coefficients on *Loans-to-assets*. None of the coefficient estimates on these additional variables supports the view that, at the margin, the LAR is determined by the precautionary and transaction motives of liquid asset holdings.

One might be concerned that the negative coefficient on *Loans-to-assets* in Panel A of Table 1 may be mechanical since at *t* an increase in loans-to-assets leaves less balance sheet room for liquid asset holdings. Because we include the lag of *Loans-to-assets*, there is no direct mechanical relation in that a given level of *Loans-to-assets* at *t-1* is consistent with any level of the LAR at *t*. In other words, the relation between the LAR and *Loans-to-assets* could be anything. This is even more the case when we lag *Loans-to-assets* by four quarters, which we do in the Internet Appendix, and find that results are unchanged. We nevertheless also estimate regressions that include no balance sheet ratios as regressors. Instead, these regressions use a proxy for lending opportunities which is the lagged eight-quarter average growth for loans. For deposits, we use the four-quarter volatility of deposits-to-assets. Our other regressors are the log of assets, net income-to-assets, ROA volatility, and the indicator variable for trading assets. The regressions include state-time and bank fixed effects. We estimate the following regression using quarterly data:

[3] Derivatives data are only available since 1995. In these regressions, our sample period is from 1995-2020.

$$LAR_{ist} = c + \beta_{LA} Log\ Assets_{ist-1} + \beta_L Loan\ growth_{ist-8,t-1} +$$

$$\beta_D Deposit\ volatility_{ist-4,t-1} + \beta_{NI} Net\ income/Assets_{ist-1} +$$

$$\beta_{ROA} ROA\ volatility_{ist-4,t-1} + \beta_{TA} Trading\ assets_{ist-1} + \gamma_{st} + \delta_{is} + \varepsilon_{ist} \quad (2)$$

We focus on the variables that are specific to the framework developed in the previous section. We expect a negative sign on *Loan growth* and a positive sign on *Deposit volatility*. We see in Panel B of Table 1 that *Loan growth* has a negative coefficient in all the regressions. The coefficient is not significant for large banks, but it is of the same magnitude as the coefficient for other banks. Turning next to *Deposit volatility*, we see that *Deposit volatility* has a positive significant coefficient for the whole sample period and for the pre-GFC period, but not for the post-GFC period. The coefficient is insignificantly negative for large banks for the pre-GFC period and insignificantly positive for the post-GFC period. It follows that we find support for our prediction of a negative relation between holdings of liquid assets and lending opportunities. The evidence on the precautionary motive for deposits is consistent with such a motive for the pre-GFC period, but not for the post-GFC period. One possible explanation for this finding is weaker lending opportunities post-GFC, such that, at the margin, liquid asset holdings tend not to be determined by the precautionary motive in this period.

Another concern with Panel A of Table 1 is the concern that aggregate reserves have to be held by banks. We address this issue by looking separately at cash holdings, which are mostly reserves, and non-cash holdings. With the portfolio motive, we expect non-cash holdings to be lower when a bank has better lending opportunities at least for the pre-GFC period when reserves did not pay interest. We estimate the regressions of Panel A of Table 1 separately for cash holdings of liquid assets and non-cash holdings of liquid assets and report the results in the Internet Appendix. The coefficient on *Loans-to-assets* is negative in all regressions, except for regressions using cash holdings for large banks in the pre-crisis period. We further find that the coefficient is greater in absolute value for non-cash liquid assets. When it comes to demand deposits, we see that the coefficient on *Demand deposits-to-assets* is positive for the cash holdings regressions and negative for the non-cash holdings regressions. This is consistent with the transaction and precautionary motives applying to cash holdings of liquid assets but not to non-cash holdings. Lastly, the negative coefficient on *Equity-to-assets* observed in Panel A of Table 1 seems to be due to a negative relation between equity and holdings of non-cash liquid assets.

We proceed to estimate regressions using changes that are in the spirit of Almeida et al. (2004). These regressions assess how changes in the use of bank resources are allocated to liquid assets and relate contemporaneous changes in the dollar amount of liquid assets to contemporaneous changes in loans and assets. With these regressions, changes in the dollar amounts of liquid assets and loans do not have a mechanical relation since both could grow as a bank's balance sheet grows. We scale the dollar changes in these and other bank balance sheet variables by lagged total assets to circumvent issues with non-stationarity, outliers, and inflation that could arise when using variables expressed in dollar terms. We also control for net income, scaled by lagged assets, for contemporaneous changes in ROA volatility, and changes in the indicator for trading assets. As in Panel A, we have state-time and bank fixed effects. We estimate the following model:

$$\Delta Liquid\ assets_{ist}/Assets_{ist-1} = \beta_L \Delta Loans_{ist}/Assets_{ist-1} + \beta_A \Delta Assets_{ist}/Assets_{ist-1} + \beta_{ROA} \Delta ROA\ volatility_{ist} + \beta_{NA} Net\ income_{ist}/Assets_{ist-1} + \beta_{TA} \Delta Trading\ assets_{ist} + \gamma_{st} + \delta_{is} + \varepsilon_{ist} \qquad (3)$$

In this regression, the dependent variable is the change in liquid assets for bank *i* in state *s* from *t-1* to *t* normalized by assets at *t-1*. The regressors are constructed in the same way. It is important to note that regression (3) is not a differenced version of regression (1) and that the regression coefficients from regression (3) are not directly comparable to the regression coefficients from regression (1). First, regression (1) uses lagged values of the explanatory variables, so that a differenced version would have lagged changes instead of contemporaneous changes. Second, regression (1) focuses on the equivalent of portfolio weights, whereas regression (3) focuses on dollar changes. To see the difference, note that for the

LAR to stay constant when assets increase, holdings of liquid assets have to increase as assets increase. Therefore, an increase in holdings of liquid assets does not imply that the LAR increases. The LAR only increases if holdings of liquid assets increase more than assets.

We show in Panel C of Table 1 estimates of regression (3). As in Panel A, we find significant negative coefficients on *ΔLoans/Assets*. In other words, when loans increase, liquid assets typically fall. We find that *ΔAssets/Assets* always has a positive significant coefficient. These coefficients suggest that if resources flow into a bank, a substantial share of these resources will be held as liquid assets.

We show additional regression estimates in the Internet Appendix. We add lagged changes to the regressions of Panel C. Doing so leads to two conclusions. First, the results we show in Panel C do not change. Second, the coefficients on the lagged changes are generally small in absolute value and typically insignificant for large banks. The adjusted R-squareds are essentially unchanged when we add the lagged changes. Second, we estimate the regressions of Panel C adding *ΔCommitments/Assets*, *ΔWholesale/Assets*, and *ΔDerivatives/Assets*. The coefficients on changes in loans, assets, and net income are not meaningfully different from the coefficients for the same variables in Panel C. *ΔCommitments/Assets* has positive significant coefficients for the whole sample period and the pre-GFC period, but an insignificant coefficient for the post-GFC period. The same is true for the coefficients on *ΔWholesale/Assets*. Lastly, *ΔDerivatives/Assets* has significant negative coefficients for each period.

We also use a different specification for changes. Instead of using dollar changes, we use growth rates as in Chakraborty, Goldstein, and MacKinlay (2018). The results using that approach are similar to the results using the dollar change specifications. In these regressions, a higher growth rate of assets is associated with a higher growth rate in liquid assets. Such a result is opposite to results in the liquid asset holdings literature for non-financial firms or from predictions of models for transaction holdings of liquid assets. It is consistent with Figure 3 when a bank experiences an increase in balance sheet size but no change in the demand for loans.

Overall, the evidence in this section supports the role of the portfolio motive for liquid asset holdings for banks in that we find a negative relation between liquid assets holdings and lagged loans-to-assets, between liquid assets holdings and lagged lending opportunities, and between changes in liquid asset holdings and changes in loans-to-assets. We find that these results hold for non-cash liquid asset holdings as well as for cash holdings.

5.2. Holdings of liquid assets and exogenous variation in loans and deposits

A concern with the results reported in Table 1 is that loans and deposits are both chosen by banks. That concern is especially acute in Panel C of Table 1 because it uses contemporaneous changes for all variables. In this section, we investigate this relation using exogenous variation in loans and deposits.

We instrument the change in loans from *t-1* to *t* (normalized by assets at *t-1*) with a Bartik-like instrumental variable (Bartik, 1991; Blanchard and Katz, 1992; Goldsmith-Pinkham, Sorkin, and Swift, 2020). Bartik-like instruments have been used before in banking, for example, in Schiantarelli, Stacchini, and Strahan (2020), Greenstone, Mas, and Nguyen (2020), and Diamond, Jiang, and Ma (2021). The approach uses as an instrument for loan changes at a bank the (predetermined) exposure of that bank to each type of loan times the aggregate loan changes for each type of loan for the type of bank at the national level. We distinguish between three types of banks: small, medium, and large. We proceed in the same way for the change in total deposits, i.e., the sum of the change in demand deposits and other deposits (normalized by assets at *t-1*), which we denote by *ΔDeposits/Assets*.

Specifically, our Bartik instrument for the change in loans is constructed as follows:

$$Bartik_{cts} = \sum_k w_{cks} g_{kts} \tag{4}$$

where *s* denotes the size group (based on total assets in constant 2018 dollars) to which bank *c* belongs: Small ($2B-$10B), Medium ($10B-$50B), and Large (>$50B); w_{cks} is bank *c*'s share of loan type *k* in bank *c*'s portfolio (loans type *k*/total loans) for the first available quarter in a five-year rolling window ending in the current quarter. We focus on the following loan types (*k*): commercial and industrial (C&I) loans, real estate (RE) loans, personal loans, and other loans. When instrumenting the change in loans, g_{kts} is computed as the aggregate dollar change in loans of type *k*, scaled by lagged aggregate assets, where aggregate numbers are computed across all banks in size bucket *s.*

We construct our Bartik instrument for the change in deposits similarly. Specifically, our Bartik instrument for changes in deposits is constructed using equation (4) above, where w_{cks} is bank *c*'s initial share of total bank funding of deposit type *k* (demand deposits or other deposits) as of the first available quarter in a five-year rolling window ending in the current quarter, g_{kts} is the aggregate dollar change in deposits of type *k,* scaled by lagged aggregate assets, where aggregate numbers are computed across all banks in size bucket *s.*

We report the results in Table 2. The regressions use bank fixed effects, but not state-time fixed effects since the Bartik instrument has a common time-varying component for all banks. We add changes in the Fed funds rate, the default spread (measured as the yield difference between BBB-rated and AAA-rated corporate bonds), the composite leading indicator, the interest rate on reserves, and the ratio of aggregate reserves to aggregate bank assets to control for macroeconomic conditions. We first show the first-stage regressions where we regress *ΔLoans/Assets* on our Bartik instrument for the change in loans, our Bartik instrument for the change in deposits, the change in the other bank characteristics we use in the regressions of Panel C of Table 1, and the variables that control for macroeconomic conditions. We report the first-stage results for *ΔLoans/Assets* for the full sample period and the pre-GFC and post-GFC periods in Columns (1) through (3). In Columns (4) through (6), we estimate the same regressions, but now the dependent variable is *ΔDeposits/Assets*. We find that the Bartik instruments are significant in all regressions.

Columns (1) through (6) of Table 2 show strong first-stage results, so that our Bartik instruments are relevant. Consequently, the first stage captures the impact of differential exposures of banks to loan types on a bank's loans and the impact of differential exposures to deposit types on a bank's deposits. These differential exposures are not affected by the aggregate variables as they are observed five years before the changes in the aggregate variables. The additional control variables capture changes in macroeconomic conditions, so that these changes can affect holdings of liquid assets directly rather than potentially through their impact on the instruments.

We now turn in Columns (7) through (9) to the second-stage results. Again, these models have bank fixed effects. We show OLS estimates of the same regressions in the Internet Appendix estimated over the same period. All OLS coefficients on the change in loans and the change in deposits are significantly different from zero. For the two-stage least squares results, we find a strong negative coefficient on the instrumented *ΔLoans/Assets* for all three periods and a strong positive coefficient on the instrumented *ΔDeposits/Assets* for all three periods. The Sanderson-Windmeijer (2016) multivariate *F*-test of excluded instruments rejects the null of weak instruments strongly.[4] These results support the role of the portfolio investment motive.

We assess the robustness of our results by estimating shares using a ten-year instead of a five-year rolling period in the Internet Appendix. The results are similar. We also estimate Table 2 adding the VIX, which shortens the sample period. We find that the coefficients on loans are similar, but the coefficient on deposits for the pre-GFC period is much smaller and insignificant. This latter finding may be due to the shorter sample period as it holds as well on the shorter sample period if we do not include the VIX.

5.3. Do banks with low holdings of liquid assets invest more in such assets following an increase in deposits?

Our framework implies that banks that have not exhausted their valuable lending opportunities will use an increase in deposits to fund more loans. In contrast, banks that have exhausted their lending opportunities will invest an increase in deposits in other assets, such as liquid assets. We proceed as in Section 5.2. using the Bartik-like instrument for the change in loans and the change in deposits. In this section, however, we are interested in whether banks with low liquid assets behave differently. If banks with low liquid assets are somehow liquidity-constrained banks, we would expect them to use additional deposits to invest more

[4] Based on the Stock and Yogo (2005) weak ID F-test critical values.

in liquid assets. Alternatively, if banks with low liquid assets are simply banks that have good lending opportunities, we would expect them to not invest more in liquid assets out of additional deposits. If banks with low holdings of liquid assets do not increase their holdings of liquid assets when their deposits increase, this would be consistent with the portfolio motive but not with the view that these banks are constrained in their holdings of liquid assets and that their holdings of liquid assets are abnormally low.

We consider a bank to have low liquid asset holdings if it has liquid asset holdings in the bottom decile of liquid asset holdings of banks in a given year. We add an indicator variable for whether a bank has low liquid asset holdings to our regressions in Table 2, together with an interaction of that variable with the instrumented *ΔLoans/Assets* and *ΔDeposits/Assets*. The results of the second-stage regressions are in Table 3. The corresponding OLS results are shown in the Internet Appendix. We show results for the whole sample period and the two subperiods. The coefficient on the indicator variable is negative and significant, so that banks with low liquidity overall tend to increase liquid assets less. Such a result is inconsistent with the view that banks with low liquidity aim to increase their liquidity to exit the low liquidity state. We then see that the interaction of the indicator variable with *ΔDeposits/Assets* is negative and significant for all three periods. It follows that banks with low holdings of liquid assets put less of an increase in deposits in liquid assets than other banks. This result is also inconsistent with the view that banks with low holdings of liquid assets are somehow liquidity-constrained and work at exiting their low liquidity state. Instead, it is consistent with the portfolio motive for liquid asset holdings, which is that banks with valuable lending opportunities have low liquid asset holdings and invest additional funds from deposits less in liquid asset holdings than banks that have less valuable lending opportunities. We also show that, as we would expect, banks with low liquidity fund less of their loans through a decrease in liquid asset holdings since the coefficient on the interaction of *ΔLoans/Assets* with the low liquid asset holdings indicator is positive and significant for all three periods.

In the Internet Appendix, we report the regression estimates of the same analysis using a ten-year rolling window and find similar results. The results are similar as well if we add changes to the VIX as an explanatory variable, which shortens the sample period. We also omit bank fixed effects. When we do so, the estimated coefficients in the second-stage on the variables of interest are significant, but the null of weak instruments is rejected more strongly.

6. The post-GFC period

In Section 5, we provided supportive evidence for the role of the portfolio investment motive in explaining banks' holdings of liquid assets. In this section, we examine whether the portfolio investment motive can help explain the growth in bank liquid asset holdings after the GFC. We show in Section 6.1 that this motive helps understand the growth in aggregate bank liquid asset holdings after the GFC. However, the time-series models estimated over the whole sample period underestimate the growth of the aggregate LAR after 2012. We show that the aggregate LAR increases more than explained by our time-series models because of the impact of regulatory changes on the largest banks in Section 6.2.

6.1. Lending opportunities and the post-GFC growth in liquid assets

To better understand the evolution of bank liquid asset holdings after the GFC, it is useful to compare the 11-year period from 2010 to 2020 to the 11-year period from 1996 to 2006. From 1996 to 2006, the growth of aggregate loans is 147% and the growth of aggregate deposits is 153%, so that the growth of loans is almost equal to the growth of deposits. During that period, liquid asset holdings grow by 99%. Turning to 2010 to 2020, the growth of deposits is 150% in contrast to a growth of loans of only 64%. With such a high growth of deposits and low growth of loans, we would expect aggregate liquid asset holdings to grow at a high rate. They grow by 217%.

To assess whether the portfolio investment motive helps explain the growth in bank holdings of liquid assets after the GFC, we estimate two time-series models. We discuss these models in turn. With the first model, with estimates shown in Column (1) of Table 4, we regress the change in aggregate LAR over a quarter on the lagged four-quarter growth rate of aggregate loans, the lagged four-quarter growth rate of aggregate deposits, the change in the 3-month Treasury bill rate, the growth in aggregate reserves, and all macroeconomic variables that we use in Tables 1 through 3. We use the change in LAR as dependent variable because LAR is non-stationary and confirm that Augmented Dickey-Fuller tests reject the null hypothesis of a unit root for all variables included in Table 4. Our use of lagged dependent variables for loan growth and deposit growth should alleviate concerns about reverse causality. Because we look at aggregate liquid asset holdings, we have only 144 observations for the whole sample. We use quarter indicator variables to account for seasonality and use Newey-West standard errors to account for serial correlation.

We find that the coefficient on loan growth is significantly negative with a value of -0.069. The magnitude of this coefficient indicates that a one-standard deviation decrease in loan growth (0.035) is associated with an increase in LAR of 24 basis points, which represents a 34% increase relative to its standard deviation (0.007). Deposit growth has a positive and marginally significant coefficient. None of the macroeconomic variables have a significant coefficient except the contemporaneous growth in reserves, which has a coefficient of 0.003 significant at the 10% level. This coefficient indicates that a one-standard deviation increase in aggregate reserves growth (0.507) is associated with an increase in LAR of 15 basis points, a 21% increase relative to its standard deviation. In Table 4, we show estimates in Column (2) of the same regression as in Column (1) except that the dependent variable is the quarterly growth rate of aggregate liquid assets. We find that the past growth rate in aggregate loans has a negative coefficient as expected and the coefficient on aggregate deposit growth is positive though not significant. The only macroeconomic variable that is significant is the growth in reserves, which has a positive coefficient.

In Panel A of Figure 4, we show the increase in the aggregate LAR of the banks in our sample from the quarter ending in June 2008 to the quarter ending in December 2020 as well as the fitted values of LAR from our time-series model. We see that the actual LAR increases by 20.8 percentage points over that period. The fitted values of our model show an increase of 12.7 percentage points. The fitted values of the model track the actual values of the aggregate LAR well until 2012. However, starting in 2013, the actual values keep increasing while the fitted values stay fairly stable, so that the fitted values underestimate the increase in LAR. The fitted values underestimate the increase in LAR further in 2020 as deposits increase sharply. We also show in Panel A of Figure 4 what the fitted values would be if loans had grown at the same rate as for the ten years before the GFC. We see that the aggregate LAR would have fallen steadily so that at the end of 2019 it would have been close to its value as of June 2008. These findings suggest that the fact that loan growth was low post-GFC makes a big difference in the evolution of the LAR. We also considered the fact that reserves increase much during the post-GFC period. The increase in reserves does not change the evolution of the LAR materially. Finally, Panel A of Figure 4 also shows the fitted values of the time-series model that excludes the lagged four-quarter growth rate of aggregate loans, and the growth in aggregate reserves, respectively. We observe that the fitted values of the time-series model are mainly driven by the growth in loans and not by the growth in reserves.

Panel B of Figure 4 shows how the growth rate of loans and the growth rate of deposits evolve during our full sample period 1984-2020. It is striking that, starting with the GFC, the two growth rates diverge with a low growth rate for loans compared to the growth rate for deposits. Given this divergence, it is not surprising that the growth rate of aggregate liquid assets is high as shown in Panel C of Figure 4. The fitted values of our regression in Column (2) of Table 4 track the actual growth rate well for much of the post-GFC period, while the loan growth observed pre-GFC would have suggested a much smaller growth in aggregate liquid assets.

6.2. Why did liquid asset holdings grow more for the largest banks?

It follows from Section 6.1 that poor loan growth explains much of the increase in aggregate liquid assets post-GFC, but nevertheless our time-series model of the aggregate LAR underestimates the LAR after 2012. In this section, we explore why the time-series model underestimates the increase in LAR.

The growth of liquid asset holdings differs sharply between the largest banks and the other banks. After the GFC, as seen in Figure 2, a large gap develops between the LAR of large banks and the LAR of small and medium banks. Before the GFC, the LAR of small banks is higher than the LAR of large banks. Immediately before the COVID crisis, the LAR of large banks (with assets in excess of $50 billion) is 7.80 percentage points higher than the LAR of small banks. As a result, the LAR difference between large and small banks at the end of 2019 is the reverse of what it was at the start of our sample in 1984 when the LAR of small banks was 8.22 percentage points higher than the LAR of large banks. Further, the average LAR of large banks keeps increasing after 2012 while the average LAR of medium and small banks falls slowly over time until 2019.

There are at least three possible changes that could help explain the difference in the evolution of liquid asset holdings between large vs. small and medium banks other than regulatory developments:

1) **Increase in aggregate reserves due to quantitative easing.** Keeping everything else the same, an increase in reserves would increase liquid asset holdings. If the increase in reserves resulting from quantitative easing affected the largest banks more than other banks, their liquid assets would have increased more.
2) **Capital depletion hypothesis**. Large banks invested more in mortgage-related securities that suffered losses during the GFC (Erel, Nadauld, and Stulz, 2014). As a result, they were more likely to be capital-constrained or at risk of being capital-constrained. To alleviate capital pressures, large banks could increase liquid asset holdings and decrease loans.
3) **Deposit inflows hypothesis.** During the GFC, some of the largest banks experienced deposit inflows because of a flight to quality (Acharya and Mora, 2015). Lending opportunities fell or did not increase commensurately. As a result, large banks had funds to invest that they could not invest in loans.

The Fed balance sheet extension can help explain the increase of reserve holdings by banks. However, it fails to explain why banks increased non-reserve liquid asset holdings as much as they did. Non-cash liquid assets-to-assets for the banking system were higher by 9.6 percentage points at the end of 2020 than immediately before the Lehman bankruptcy, while cash liquid assets-to-assets, which include reserves, were higher by 10.5 percentage points. The capital depletion hypothesis could plausibly explain why holdings of liquid assets increase sharply during the GFC, but it does not really explain why liquid assets keep increasing throughout the post-GFC period. With the capital depletion hypothesis, we would expect liquid assets to fall as banks rebuild their capital positions. While liquid asset holdings decrease for the other banks, they increase for large banks. A similar argument holds for the increase in deposits. We would expect deposits resulting from a flight to safety to flow out of banks when economic conditions return to a more normal state.

Bank regulatory capital requirements in the US were affected by two major regulatory changes. The first change was the Basle III Accord published in November 2010. The second change was the passage of Dodd-Frank in July 2010. Banks started taking steps to meet the expected requirements before they became effective.[5] Large banks experience higher capital requirement increases relative to other banks.[6] Within large banks, the increase in capital requirements is larger for banks that exceed the $250 billion of assets threshold.[7] Note that most liquid assets have no risk-based capital requirement or a low risk-based capital requirement compared to risky loans. The differential increase in capital requirements means that, for the same loan, a large bank must hold more capital than a small bank, so that in our framework, the risk-adjusted demand curve for the loans of a large bank shifts to the left relative to the risk-adjusted demand curve for the loans of a smaller banks. Consequently, the larger banks lend less and hold more liquid assets.

Before the GFC, there were no liquidity requirements for banks. These requirements are introduced in the Basel III accord in 2010 and implemented by countries in the following years. In the US, the LCR requirement for banks becomes effective on January 1, 2015. The final version of the LCR applies to bank holding companies with assets in excess of $250 billion starting from January 1, 2015, but with full implementation in 2017. Banking organizations with assets greater than $50 billion are subject to a modified LCR starting in 2016. As part of enhanced supervision, these banking organizations are also subject to regulation YY that requires them to have a liquidity risk management framework and to conduct liquidity stress tests. These risk management requirements are more onerous for the largest banks, those with assets

[5] For instance, JPMorgan Chase took steps to decrease its risk-weighted assets to meet Basel III requirements in 2011 (Zeissler, Ikeda, and Metrick, 2019).
[6] See Davis Polk, U.S. Basel III Final Rule: A visual memorandum, April 30, 2015, for a detailed summary of the changes in capital requirements resulting from Basel III.
[7] On May 24, 2018, Congress adopted the Economic Growth, Regulatory Relief, and Consumer Protection Act (EGRRCPA). This Act led to regulatory relief for banks with assets lower than $250 billion as of November 1, 2019. With our sample, the period during which banks are affected by this Act is too short to be used to test further the implications of liquidity requirements.

greater than $250 billion, in part because of the constraints they put on the management of intra-day liquidity (Copeland et al., 2022).

A formal examination of the impact of the regulatory changes faces some important obstacles. First, as discussed, this is not a situation where banks have one liquidity policy until the changes are implemented and another one when the changes are implemented. Banks get ready for the implementation of new regulations. The second obstacle is that there are multiple regulatory changes. The LCR is not the change on which bank CEOs focus in the early years after the GFC. They focus much more on the increase in capital requirements and the stress tests.[8] Third, it is not clear when the banks thought that they knew enough about the regulatory changes to fully adjust their policies. Fourth, the banks most affected by the regulatory changes are the largest banks, but there are few of those. After excluding foreign banks and trust banks, there are seven banks with assets in excess of $250 billion. Fifth, the complexity of the changes makes it impossible for researchers to attempt to measure capital requirements and the liquidity requirements directly.[9]

By 2013, both the capital requirement changes and the details of the liquidity requirements are generally known. The Federal Reserve publishes key documents that year.[10] The final version of the LCR is published in 2014. Capital requirements and liquidity requirements are implemented over time. We show results where we take 2013 to be the treatment year. We discuss results where we take 2014 to be the treatment year and show these results in the Internet Appendix.

We now turn to a more detailed examination of how 1) the LAR, 2) Tier 1 equity-to-assets, and 3) risk-weighted assets change after the treatment year. As discussed in Section 4, we would expect the regulatory reforms to increase the LAR for banks that have a low LAR because they have good lending opportunities.

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[8] For instance, we reviewed the CEO's letter to shareholders for JP Morgan Chase for 2013 and 2014. There is almost no discussion of the LCR, but considerable discussion of the various new capital requirements and changes in capital requirements.

[9] In its 2014 letter to the shareholders, the CEO of JPMorgan Chase states that the bank has 27 different capital requirements and more than 500 requirements for liquidity (see page 23 of the Annual Report for 2014 of JPMorgan Chase Co.).

[10] See Basel Regulatory Framework, Recent Updates, Board of Governors of the Federal Reserve System, https://www.federalreserve.gov/supervisionreg/basel/basel-default.htm.

For such banks, the increase in LAR should be accompanied by a decrease in loans. We would also expect Tier 1 capital to increase for banks that have a low Tier 1 ratio. Finally, we would expect loans to decrease. As discussed, the regulatory changes affect the largest banks, i.e., those with assets in excess of $250 billion, faster and to a greater extent. We, therefore, consider two groups of treated banks. The first group consists of banks with assets in excess of $250 billion. The second group consists of banks with assets between $50 billion and $250 billion. The non-treated banks are the banks with assets below $50 billion. The treatment year (year *t)* is 2013. We classify banks into size groups based on their status two years before treatment (*t-2*, as of the end of 2011). We estimate the regressions over the period 2010 to 2015.

We show results in Table 5. We include interactions between indicators for our treatment groups, *Large banks >$250B* and *Large Banks $50-$250B*, respectively, and an indicator, *Post*, which equals one starting in the year 2013. We also include interactions with *Pre*, an indicator equal to one for 2011. All regressions use bank fixed effects and time fixed effects.[11] The regressions estimated in Columns (1) through (3) have no controls. Columns (4) to (6) use controls observed in the year 2011 and interact these controls with the *Post* indicator variable.

Irrespective of the controls, there appears to be a large treatment effect for LAR for the largest banks. In Column (4), the LAR of the largest banks increases by 7.5 percentage points. To put this treatment effect in perspective, from the start of 2010 to the end of 2019, the LAR of the largest banks increases relative to the LAR of the smallest banks by 12.44 percentage points. As a result, the treatment effect appears to explain roughly 60% of the relative increase in the LAR of the largest banks. As expected, the treatment effect for the banks with assets between $50 billion and $250 billion is less than the treatment effect for the largest banks. We find a treatment effect for the largest banks for Tier 1 in Column (2) but not in Column (5). Lastly, we find that loans fall for the largest banks but not for the large banks in Column (6), but there is no treatment effect for loans in Columns (3).

[11] State-time fixed effects are questionable when we focus on the largest banks that are global in nature.

We check whether the parallel trends assumption holds for our analysis of the treatment effect for the LAR and report the results in the Internet Appendix in Figure IA.1. We find that the parallel trends assumption holds irrespective of how we deal with controls. We then explore the sensitivity of our results to changing the treatment year. If we use 2014, the results are largely similar with two important differences. First, the negative treatment effect on loans holds across specifications, but the *Pre* indicator variables in the regressions for loans are negative. Second, the parallel trends assumption holds marginally for LAR.

If the LAR is increased because of the LCR requirement, we would expect the LAR to increase more for banks with a low LAR. If the LAR is increased because of the increase in capital requirements, we would expect the LAR to increase more for banks with a low Tier 1 ratio. In Column (7), we interact *Post* × *Large > $250* with an indicator variable that takes value 1 if a bank has a LAR in the bottom quartile for the banks with assets greater than $250 billion in 2011. We proceed in the same way for *Post* × *Large > $50*, where the group of banks is defined as banks with assets greater than $50 billion and lower than $250 billion. The triple interaction is significant for the banks with assets in excess of $250 billion, but not for the banks with assets between $50 billion and $250 billion. Next, we define the indicator variable *Low* to take value 1 for a bank if its Tier 1 ratio is below the lowest quartile of the distribution for the bank's size group. The results are supportive of the effect of the increase in capital requirements on LAR. The coefficient on the triple interaction for the largest banks is positive and significant. A caveat with the results is that the triple interaction of the *Low* indicator variable with *Pre* × *Large > $250* has a positive and significant coefficient. A plausible explanation for this is that the largest banks started building up capital immediately after the adoption of Basel III.

Table 5 suggests that both the LCR and the increase in capital requirements have a treatment effect on the LAR of the largest banks. While the increase in LAR for the largest banks can be attributed at least in part to regulatory changes, it cannot be attributed exclusively to the LCR.

7. Robustness

We examine the robustness of our results to alternative definitions of LAR and alternate samples extensively. We report the results in the Internet Appendix. Panel A of Figure IA.2. shows the evolution of the aggregate LAR for the alternate definitions. We specifically find:

1) Our conclusions generally hold if we use bank holding company data and restrict our sample to bank holding companies.
2) Our conclusions generally hold if we include Fed funds and reverse-repos in our definition of liquid assets. The use of reverse-repos substantially increases the level of the LAR but does not materially change the time-series evolution of the LAR.
3) Our results are not explained by changes in the outstanding amount of Treasuries over time. Specifically, our results hold if we remove Treasuries from the definition of the LAR. Panel B of Figure IA.2. shows the evolution of the Treasuries held as a percentage of liquid assets holdings. Interestingly, Treasuries were a larger component of the LAR in the early 1990s than after the GFC.

8. Conclusion

As recent events have made clear, banks hold large amounts of liquid assets and they can make losses on these liquid assets because they are exposed to interest rate changes. These liquid assets are important for the financial strength of banks and for the stability of the financial system. Given the importance of these liquid assets, we would expect that financial economists would have produced much empirical research to help us understand the magnitude of bank liquid asset holdings, but this is not the case. In this paper, we investigate the determinants of liquid asset holdings for banks and the evolution of these assets over our sample period from 1984 to 2020. We test a simple motive for liquid asset holdings for banks, the portfolio investment motive, where banks with better lending opportunities hold fewer liquid assets. We provide empirical evidence that is supportive of that prediction. We further predict that increases in deposits that are not accompanied by increases in lending opportunities lead banks to hold more liquid assets. We also find supportive evidence for that prediction. Our evidence is supportive of the portfolio investment motive for bank holding liquid assets both before and after the GFC. We find that the increase in holdings of liquid assets by banks after the GFC can be explained by lower lending opportunities, which with the portfolio investment motive would cause them to hold more liquid assets. However, the holdings of liquid assets of the largest banks are much larger after the GFC than before. We find that this change in relative liquid asset holdings can at least in part be explained by regulatory changes concerning both liquid asset holdings and capital requirements that impacted the largest banks.

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Table 1. Determinants of liquid asset holdings of banks

The table shows results from regressions of liquid asset holdings for banks. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). In Panels A and B, the dependent variable is the liquid asset ratio, *LAR*-the sum of cash holdings and non-cash liquid assets, scaled by total assets. In Panel C, , the dependent variable is *ΔLiquid assets-to-assets* – the change in liquid assets for bank *i* from *t-1* to *t* normalized by assets at *t-1*. The sample period is 1984-2020. Columns (1)-(3) of Panels A and B show results using three periods: the full sample period, the pre-GFC period, and the post-GFC period, respectively. In Columns (4)-(7), we show results separately for large banks (>$50B) and other banks (<$50B in assets) for the pre-crisis and post-crisis periods, respectively. Regressors include *Log(assets)*, the natural log of book value of assets; *Loans-to-assets*, total loans-to-assets; *Demand deposits-to-assets*, demand deposits-to-assets; *Other deposits-to-assets*, total deposits minus demand deposits, scaled by assets; *Equity-to-assets*, equity-to-assets; *Net income-to-assets*, net income scaled by assets*; ROA volatility*, the standard deviation of return on assets (ROA) over the prior four quarters, and *Trading* , an indicator equal to one for banks with trading assets as of the prior quarter-end. In Panel B, regressors include *Loan growth* – lagged eight-quarter average growth for loans, and *Deposit volatility*, the standard deviation of deposits-to-assets over the prior four quarters. Controls in Panel C include *Net income$_t$-to-assets$_{t-1}$;* all other controls are measured as changes from *t-1* to *t* normalized by assets at *t-1*, except for *ΔROA volatility*, and *ΔTrading assets*, which are measured as changes from *t-1* to *t*. We report *t*-statistics based on standard errors clustered at the bank level in parentheses. Bank and state-year fixed effects are included in all modes. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Determinants of LAR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	LAR	LAR	LAR	LAR	LAR	LAR	LAR
Sample period:	1984-2020	1984-2006	2010-2020	1984-2006		2010-2020	
				Other banks	Large banks	Other banks	Large banks
Log(assets)$_{t-1}$	-0.004	-0.005	-0.018***	-0.005	0.005	-0.019***	0.001
	(-0.82)	(-1.14)	(-2.96)	(-0.85)	(0.23)	(-2.92)	(0.04)
Loans-to-assets$_{t-1}$	-0.509***	-0.444***	-0.602***	-0.463***	-0.208	-0.595***	-0.519***
	(-17.23)	(-15.40)	(-15.20)	(-15.41)	(-1.48)	(-14.32)	(-9.04)
Demand deposits-to-assets$_{t-1}$	0.098	-0.046	0.077*	-0.048	0.265**	0.034	-0.135
	(1.57)	(-0.95)	(1.67)	(-0.93)	(2.59)	(0.70)	(-0.75)
Other deposits-to-assets$_{t-1}$	0.001	-0.037	0.056	-0.042	0.036	0.022	0.037
	(0.03)	(-1.36)	(1.38)	(-1.37)	(0.46)	(0.49)	(0.41)
Equity-to-assets$_{t-1}$	-0.338***	-0.343***	-0.323***	-0.353***	-0.136	-0.246**	-0.505**
	(-4.96)	(-5.51)	(-3.23)	(-5.51)	(-0.81)	(-2.41)	(-2.42)
Net income-to-assets$_{t-1}$	0.028	0.709*	-1.143***	0.578	4.205***	-1.190***	-0.488
	(0.10)	(1.94)	(-2.95)	(1.55)	(3.28)	(-2.98)	(-0.32)
ROA volatility$_{t-1}$	-0.785*	-0.314	0.450	-0.673	1.378	0.641	2.014
	(-1.65)	(-0.63)	(0.63)	(-1.37)	(0.83)	(0.91)	(0.93)
Trading assets$_{t-1}$	-0.008**	-0.007**	-0.002	-0.007**	-0.019**	-0.003	0.012
	(-2.44)	(-2.09)	(-0.56)	(-2.19)	(-2.39)	(-0.57)	(1.46)
Intercept	0.621***	0.641***	0.876***	0.648***	0.180	0.908***	0.570
	(8.60)	(7.95)	(8.66)	(7.08)	(0.37)	(8.17)	(1.09)
Observations	47,322	29,656	13,921	27,779	1,508	12,325	1,367
Adjusted R^2	0.815	0.825	0.893	0.829	0.756	0.892	0.920
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 1. Determinants of liquid asset holdings of banks – continued

Panel B. Determinants of LAR: Loan growth and deposit volatility							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	LAR	LAR	LAR	LAR	LAR	LAR	LAR
Sample period:	1984-2020	1984-2006	2010-2020	1984-2006		2010-2020	
				Other banks	Large banks	Other banks	Large banks
Log(assets)$_{t-1}$	-0.003	0.001	-0.027***	0.003	0.012	-0.025**	0.014
	(-0.41)	(0.20)	(-2.86)	(0.53)	(0.78)	(-2.44)	(0.29)
Loan growth$_{t-8,t-1}$	-0.114***	-0.098**	-0.137**	-0.092*	-0.108	-0.138**	-0.109
	(-3.00)	(-2.12)	(-2.16)	(-1.89)	(-0.83)	(-2.15)	(-0.48)
Deposit volatility$_{t-1}$	0.168***	0.227***	-0.189*	0.233***	-0.200	-0.203*	0.209
	(2.91)	(3.62)	(-1.83)	(3.55)	(-0.96)	(-1.73)	(1.04)
Net income-to-assets$_{t-1}$	-0.468	-0.148	-2.127***	-0.369	3.876***	-1.863***	-0.169
	(-1.16)	(-0.28)	(-3.60)	(-0.68)	(3.14)	(-2.96)	(-0.08)
ROA volatility$_{t-1}$	-0.378	-0.826	3.118***	-1.336*	1.879	3.497***	1.548
	(-0.58)	(-1.15)	(3.02)	(-1.79)	(1.07)	(3.19)	(0.58)
Trading assets$_{t-1}$	-0.010**	-0.003	-0.010	-0.003	-0.014	-0.012	0.059***
	(-2.22)	(-0.62)	(-1.31)	(-0.69)	(-1.24)	(-1.51)	(2.82)
Intercept	0.268**	0.209**	0.646***	0.180*	-0.051	0.595***	-0.058
	(2.50)	(2.22)	(4.37)	(1.81)	(-0.17)	(3.84)	(-0.07)
Observations	47,207	29,616	13,873	27,739	1,508	12,277	1,367
Adjusted R^2	0.715	0.752	0.830	0.754	0.740	0.829	0.886
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C. Determinants of changes in liquid asset holdings							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	*ΔLiquid assets*$_t$*-to-assets*$_{t-1}$						
Sample period:	1984-2020	1984-2006	2010-2020	1984-2006		2010-2020	
				Other banks	Large banks	Other banks	Large banks
ΔLoans$_t$*/assets*$_{t-1}$	-0.419***	-0.324***	-0.725***	-0.329***	-0.158*	-0.715***	-1.006***
	(-20.12)	(-14.01)	(-16.60)	(-13.83)	(-1.87)	(-16.01)	(-21.27)
ΔAssets$_t$*/assets*$_{t-1}$	0.469***	0.414***	0.659***	0.420***	0.269***	0.652***	0.835***
	(30.85)	(24.19)	(22.72)	(23.66)	(4.76)	(21.79)	(25.22)
Net income$_t$*/assets*$_{t-1}$	0.142	0.447***	-0.551***	0.462***	0.941	-0.503***	-1.397**
	(1.50)	(3.10)	(-3.60)	(3.16)	(1.05)	(-3.05)	(-2.12)
ΔROA volatility$_{t-1,t}$	0.281	0.402*	0.291	0.411*	0.647	0.412	-3.236**
	(1.61)	(1.78)	(0.98)	(1.69)	(1.18)	(1.46)	(-2.31)
ΔTrading assets$_{t-1,t}$	-0.000	0.000	-0.002	0.000	-0.003	-0.003	0.005
	(-0.07)	(0.18)	(-1.04)	(0.22)	(-0.90)	(-1.14)	(0.46)
Intercept	-0.000	-0.001***	0.002***	-0.001***	-0.003	0.002***	0.006***
	(-0.33)	(-3.53)	(5.63)	(-3.38)	(-1.37)	(4.54)	(2.99)
Observations	47,248	29,600	13,907	27,725	1,507	12,312	1,366
Adjusted R^2	0.512	0.468	0.706	0.469	0.435	0.718	0.674
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Exogenous variation in loans and deposits and bank holdings of liquid assets

The table shows first- and second-stage results from 2SLS regressions of liquid asset holdings for banks. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). We instrument Δ*Loans-to-assets*$_{t-1}$ and (Δ*Deposits-to-assets*$_{t-1}$) using Bartik-like instruments. The approach uses as an instrument for loan (deposit) changes at a bank the predetermined exposure of that bank to each of four loan types (two deposit types) times the aggregate loan (deposit) changes for each type of loan (deposits) for banks of the same type at the national level. Predetermined exposures (loan or deposit shares) are chosen for the first available quarter in a five-year rolling window ending in the current quarter. We distinguish between three types of banks: small, medium, and large; four loan types: Commercial and industrial (C&I) loans, real estate (RE) loans, personal loans, and other loans; and two deposit types: demand deposits and other deposits. When instrumenting Δ*Loans*$_t$*-to-assets*$_{t-1}$ (Δ*Deposits-to-assets*$_{t-1}$), we use the aggregate $ change in each loan (deposit) type, scaled by lagged aggregate assets, where we aggregate across all banks in group size *s*. We show first-stage results in Columns (1)-(6) and second-stage results using Δ*Liquid assets-to-assets* as the dependent variable in Columns (7)-(9). The sample period is 1984-2020 and we show results for three periods: the full sample period, the pre-GFC period, and the post-GFC period, respectively. Regressors include *Net income*$_t$*-to-assets*$_{t-1}$; Δ*ROA volatility;* Δ*Trading assets;* Δ*Fed funds rate;* Δ*Default spread;* Δ*Composite leading indicator;* Δ*Interest on excess reserves*, and Δ*Aggregate reserves-to-assets.* We report *t*-statistics based on standard errors clustered at the bank level in parentheses. We report the Sanderson-Windmeijer multivariate *F*-test of excluded instruments. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 2. Exogenous variation in loans and deposits and bank holdings of liquid assets – continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	*ΔLoans$_t$-to-assets$_{t-1}$*			*ΔDeposits$_t$-to-assets$_{t-1}$*			*ΔLiquid assets$_t$-to-assets$_{t-1}$*		
	First-stage			First-stage			Second-stage		
Sample period:	1984-2020	1984-2006	2010-2020	1984-2020	1984-2006	2010-2020	1984-2020	1984-2006	2010-2020
ΔLoans$_t$/assets$_{t-1}$ (Instrumented)[A]							-0.268***	-0.305***	-0.270**
							(-4.89)	(-4.24)	(-2.44)
ΔDeposits$_t$ /assets$_{t-1}$ (Instrumented)[B]							0.447***	0.365***	0.482***
							(16.41)	(12.72)	(7.05)
Bartik instrument: ΔLoans	0.700***	1.346***	0.376***	-0.266***	-1.066***	-0.227**			
	(6.81)	(5.01)	(3.62)	(-3.07)	(-4.67)	(-2.33)			
Bartik instrument: ΔDeposits	0.477***	0.196**	0.524***	1.551***	2.100***	0.916***			
	(9.95)	(2.19)	(7.77)	(22.34)	(18.75)	(9.50)			
Net income$_t$/assets$_{t-1}$	3.771***	4.713***	2.073***	3.448***	4.949***	1.603***	0.458**	1.439***	-0.202
	(12.57)	(8.65)	(4.31)	(10.60)	(8.38)	(2.73)	(2.35)	(3.66)	(-0.81)
ΔROA volatility$_{t-1,t}$	0.078	0.058	-0.485	0.505**	0.462	-1.068*	-0.233*	-0.216	0.325
	(0.39)	(0.26)	(-1.08)	(2.03)	(1.62)	(-1.93)	(-1.78)	(-1.34)	(1.15)
ΔTrading assets$_{t-1,t}$	-0.001	-0.002	0.000	-0.002	-0.003*	0.000	-0.001	-0.001	-0.006
	(-0.81)	(-1.06)	(0.03)	(-1.23)	(-1.79)	(0.06)	(-1.35)	(-1.22)	(-1.55)
ΔFed funds rate$_{t-1,t}$	0.001**	0.001	0.026***	-0.003***	-0.002***	0.034***	-0.001***	-0.001**	0.002
	(2.20)	(1.19)	(5.49)	(-4.64)	(-3.04)	(5.55)	(-2.63)	(-2.43)	(0.77)
ΔDefault spread$_{t-1,t}$	0.982***	1.612***	0.561**	0.941***	2.264***	0.309	0.442***	1.110***	-0.181
	(6.55)	(5.61)	(2.11)	(4.95)	(6.68)	(0.84)	(4.47)	(5.24)	(-1.12)
ΔComposite leading indicator$_{t-1,t}$	-0.002***	-0.003***	-0.004***	0.002***	-0.002**	-0.001	0.001***	0.001**	-0.000
	(-3.81)	(-3.28)	(-4.73)	(3.58)	(-2.16)	(-1.17)	(3.62)	(2.55)	(-0.23)
ΔInterest on excess reserves$_{t-1,t}$	-1.066***		-2.687***	-0.921***		-4.081***	-0.248*		-0.234
	(-5.60)		(-7.76)	(-4.19)		(-9.76)	(-1.93)		(-0.81)
ΔAggregate reserves$_t$-to-assets$_{t-1}$	-0.285***	2.590***	-0.114**	-0.201***	3.792***	0.096	0.118***	2.189***	0.091***
	(-10.18)	(4.20)	(-2.42)	(-4.78)	(5.20)	(1.55)	(5.15)	(5.02)	(2.63)
Observations	45,074	28,667	12,774	45,074	28,667	12,774	45,074	28,667	12,774
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	No	No	No	No	No	No	No	No	No
SW F-test of excl. instrument [A]							*75.59*	*41.09*	*28.31*
SW F-test of excl. instrument [B]							*239.70*	*469.93*	*66.22*

Table 3. Low levels of liquid asset holdings and exogenous variation in loans and deposits

The table shows second-stage results from 2SLS regressions of changes in deposits and in liquid asset holdings for banks. The sample consists of US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). We instrument *ΔLoans-to-assets*$_{t-1}$ and *(ΔDeposits-to-assets*$_{t-1}$*)* using Bartik-like instruments, as discussed in Table 2. This table shows results from interactions between the instrumented *ΔLoans-to-assets*$_{t-1}$ and *ΔDeposits-to-assets*$_{t-1}$ and *Low LAR*, an indicator equal to one for banks with an *LAR* in the bottom decile of the distribution in a year. The sample period is 1984-2020 and we show results using three periods: the full sample period, the pre-GFC period, and the post-GFC period, respectively. Regressors include *Net income*$_t$*-to-assets*$_{t-1}$; *ΔROA volatility; ΔTrading assets; ΔFed funds rate; ΔDefault spread; ΔComposite leading indicator; ΔInterest on excess reserves*, and *ΔAggregate reserves-to-assets.* We report *t*-statistics based on standard errors clustered at the bank level in parentheses. We report *p*-values from *F*-tests of the sum of the coefficients *ΔLoans (ΔDeposits)* x *Low LAR*+ *ΔLoans (ΔDeposits*) = 0 and the Sanderson-Windmeijer multivariate F-test of excluded instruments. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)
Dependent variable:	*ΔLiquid assets*$_t$*-to-assets*$_{t-1}$		
	1984-2020	1984-2006	2010-2020
ΔLoans$_t$*/assets*$_{t-1}$ *(Instrumented) [A]*	-0.382***	-0.455***	-0.362***
	(-5.82)	(-4.72)	(-2.69)
ΔDeposits$_t$ */assets*$_{t-1}$ *(Instrumented)[B]*	0.504***	0.415***	0.556***
	(17.74)	(13.29)	(7.23)
ΔLoans$_t$*/assets*$_{t-1}$ x *Low LAR [A']*	0.390***	0.493***	0.354**
	(5.75)	(5.21)	(2.52)
ΔDeposits$_t$ */assets*$_{t-1}$ x *Low LAR [B']*	-0.421***	-0.355***	-0.514***
	(-7.46)	(-5.36)	(-4.31)
Low LAR	-0.015***	-0.022***	-0.010***
	(-9.16)	(-8.35)	(-3.90)
Net income$_t$*/assets*$_{t-1}$	0.746***	2.015***	-0.024
	(3.46)	(4.24)	(-0.10)
ΔROA volatility$_{t-1,t}$	-0.244*	-0.224	0.231
	(-1.90)	(-1.37)	(0.89)
ΔTrading assets$_{t-1,t}$	-0.001	-0.001	-0.005
	(-1.29)	(-1.12)	(-1.45)
ΔFed funds rate$_{t-1,t}$	-0.001**	-0.001*	0.004
	(-2.07)	(-1.76)	(1.33)
ΔDefault spread$_{t-1,t}$	0.425***	1.180***	-0.240
	(4.35)	(5.17)	(-1.55)
ΔComposite leading indicator$_{t-1,t}$	0.001**	0.001	-0.001
	(2.42)	(1.57)	(-0.88)
ΔInterest on excess reserves$_{t,t-1}$	-0.270**		-0.266
	(-2.15)		(-0.94)
ΔAggregate reserves$_t$*-to-assets*$_{t-1}$	0.103***	2.272***	0.091***
	(4.41)	(4.97)	(2.71)
Observations	45,074	28,667	12,774
Bank fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No
p-value [A+A']=0	0.842	0.446	0.924
p-value [B+B']=0	0.112	0.309	0.682
SW F-test of excl. instrument [A]	101.16	55.81	29.94
SW F-test of excl. instrument [B]	212.34	312.13	54.04

Table 4. Explaining the change in aggregate LAR and growth in aggregate liquid assets post-GFC

The table shows results from time-series regressions of aggregate holdings of liquid assets. Liquid assets, loans, and deposits are aggregated across our full sample of banks, which consists of US-chartered commercial banks with assets that exceed \$2 billion (in constant 2018 dollars). In Column (1), the dependent variable is $\Delta LAR_{t-1,t}$, the quarterly change in aggregate LAR (the sum of cash holdings and non-cash liquid assets, scaled by total assets). In Column (2), the dependent variable is *Growth in liquid assets*$_{t-1,t}$ –the quarterly growth in aggregate liquid assets. The sample period is 1984-2020. Regressors include *Loan growth*$_{t-4,t-1,}$ *Deposit growth*$_{t-4,t-1}$; *ΔFed funds rate*$_{t-1,t}$; *ΔDefault spread*$_{t-1,t}$; *ΔComposite leading indicator*$_{t-1,t}$; *ΔT-bill rate*$_{t-1,t}$; *ΔInterest on excess reserves*$_{t-1,t}$, and *Growth in aggregate reserves*$_{t-1,t}$. We report *t*-statistics based on Newey-West standard errors to account for serial correlation. We include quarter indicator variables to account for seasonality. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable:	*ΔLAR*$_{t-1,t}$	*Growth in liquid assets*$_{t-1,t}$
	(1)	(2)
Loan growth$_{t-4, t-1}$	-0.069***	-0.276**
	(-3.90)	(-2.55)
Deposit growth$_{t-4, t-1}$	0.045*	0.194
	(1.95)	(1.52)
ΔFed funds rate$_{t-1,t}$	-0.004	-0.015
	(-1.41)	(-0.89)
ΔDefault spread$_{t-1,t}$	0.417	4.284
	(1.06)	(1.57)
ΔComposite leading indicator$_{t-1,t}$	-0.001	-0.009
	(-0.65)	(-1.14)
ΔT-bill rate$_{t-1,t}$	0.002	0.012
	(0.87)	(0.77)
ΔInterest rate on excess reserves$_{t-1,t}$	-0.492	-0.983
	(-0.88)	(-0.24)
Growth in reserves $_{t-1,t}$	0.003*	0.028**
	(1.87)	(2.44)
Q1	-0.003*	-0.022*
	(-1.79)	(-1.95)
Q2	-0.003**	-0.016*
	(-2.55)	(-1.97)
Q3	-0.004**	-0.024***
	(-2.43)	(-2.75)
Constant	0.003***	0.029***
	(3.02)	(4.00)
Observations	144	144
Adjusted R^2	0.248	0.282

Table 5. Difference-in-differences regressions around the adoption of the LCR

The table shows results from difference-in-differences regressions for the five-year [-2,+3] window around the adoption of the LCR, where the treatment year (t=1) is 2013. The sample consists of US-chartered commercial banks with assets that exceed $2B billion (in constant 2018 dollars). We exclude trust banks and banks with foreign ownership, and we only include the largest entity within a multibank holding company. Dependent variables are *LAR* – the sum of cash holdings and non-cash liquid assets, scaled by total assets; *Tier 1 capital ratio* –the total Tier 1 capital, scaled by risk-weighted assets, and *Loans-to-assets*. We have two groups of treated banks, sorted by size as of *t-1* (2011): *Large >$250B*, banks with assets in excess of $250B (in constant 2018 dollars) and *Large $50-$250B*, banks with assets between $50B and $250B. The control group includes banks with assets below $50B. *Post* is an indicator variable equal to one starting in 2013. *Pre* is an indicator equal to one for 2011 and zero otherwise. In column (7) and (8) we show regressions using LAR as the dependent variable and use triple interactions with an indicator equal to one for banks with *LAR (Tier 1 capital)* in the bottom quartile in its size group as of *t-1*. Regressors include *Log(assets)*, the natural log of book value of assets; *Demand deposits-to-assets*, demand deposits-to-assets; *Other deposits-to-assets*, total deposits minus demand deposits, scaled by assets; *Equity-to-assets*, equity-to-assets; *Net income-to-assets; ROA volatility*, the standard deviation of return on assets (ROA) over the prior four quarters, and *Trading assets*, an indicator equal to one for banks with trading assets as of the prior quarter-end. Models (1)-(3) show results without controls. Models (4)-(6) show results using interactions between regressors measured as of *t-1* and *Post*. Models (7)-(9) show results using lagged regressors. We report *t*-statistics based on standard errors clustered at the bank level in parentheses. All variables are defined in the Appendix. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 5. Difference-in-differences regressions around the adoption of the LCR – continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	LAR	Tier 1	Loans-to-assets	LAR	Tier 1	Loans-to-assets	LAR	LAR
Pre × Large >$250B	-0.004	-0.002	0.002	-0.004	-0.001	0.002	-0.008	-0.012*
	(-0.60)	(-1.12)	(0.30)	(-0.53)	(-0.83)	(0.29)	(-0.88)	(-1.97)
Pre × Large $50-$250B	0.000	-0.001	0.005	0.001	-0.000	0.005	0.006	0.003
	(0.05)	(-0.45)	(1.22)	(0.13)	(-0.12)	(1.18)	(0.71)	(0.28)
Post × Large >$250B	0.068***	0.011**	-0.022	0.075***	0.013	-0.050*	0.054**	0.054*
	(4.00)	(1.99)	(-1.41)	(2.69)	(0.91)	(-1.76)	(2.25)	(1.92)
Post × Large $50-$250B	0.033***	0.004	0.002	0.033*	0.014	-0.019	0.043**	0.030
	(2.69)	(0.64)	(0.09)	(1.77)	(1.30)	(-0.86)	(2.31)	(1.37)
Pre × Large >$250 × Low LAR							0.018	
							(1.51)	
Pre × Large >$50 × Low LAR							-0.022	
							(-1.19)	
Post × Large >$250 × Low LAR							0.067***	
							(3.39)	
Post × Large >$50 × Low LAR							-0.034	
							(-1.07)	
Pre × Large >$250 × Low Tier 1								0.025***
								(2.72)
Pre × Large >$50 × Low Tier 1								-0.008
								(-0.63)
Post × Large >$250 × Low Tier 1								0.070**
								(2.12)
Post × Large >$50 × Low Tier 1								0.020
								(0.76)
Post × Log(assets)$_{t-1}$				0.002	-0.000	0.002	0.002	0.002
				(0.40)	(-0.01)	(0.44)	(0.31)	(0.30)
Post × Loans-to-assets$_{t-1}$				0.102***	0.061**		0.074**	0.119***
				(3.21)	(2.58)		(2.14)	(3.47)
Post × Demand deposits-to-assets$_{t-1}$				0.104	0.014	-0.203**	0.123*	0.098
				(1.36)	(0.37)	(-2.16)	(1.65)	(1.30)
Post × Other deposits-to-assets$_{t-1}$				0.033	0.015	-0.081*	0.041	0.029
				(0.82)	(0.69)	(-1.73)	(1.07)	(0.72)
Post × Equity-to-assets$_{t-1}$				-0.045	-0.613***	0.251*	-0.021	-0.142
				(-0.38)	(-3.27)	(1.78)	(-0.19)	(-0.99)
Post × Net income-to-assets$_{t-1}$				-3.318*	-0.392	2.702	-3.244*	-3.604**
				(-1.91)	(-0.50)	(1.44)	(-1.81)	(-2.05)
Post × ROA volatility$_{t-1}$				-1.688	-2.037	1.747	-1.341	-2.098
				(-0.68)	(-1.05)	(0.66)	(-0.55)	(-0.88)
Post × Trading assets$_{t-1}$				-0.003	0.005	0.002	-0.003	-0.000
				(-0.25)	(1.28)	(0.16)	(-0.29)	(-0.03)
Post × Low LAR							0.014*	
							(1.75)	
Pre × Low LAR							-0.016***	
							(-2.69)	
Post × Low Tier 1								-0.018**
								(-2.07)
Pre × Low Tier 1								-0.001
								(-0.21)
Observations	5,673	5,669	5,673	4,964	4,960	4,964	4,964	4,964
Adjusted R^2	0.860	0.611	0.899	0.861	0.650	0.902	0.863	0.862
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 1. Aggregate liquid asset holdings and loans

The figure shows the aggregate liquid assets-to-assets ratio (*LAR*), the *Loans-to-assets* ratio, and the components of the *LAR*: *Cash-to-assets* and *Non-cash LAR* for US-chartered commercial banks with assets that exceed $2 billion (in constant 2018 dollars). The aggregate *LAR* (*Loans-to-assets*) is computed by summing liquid assets (loans) for all banks in the sample and dividing them by the sum of assets for all banks. Liquid assets represent the sum of cash holdings and non-cash liquid assets. Cash holdings include vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. Non-cash liquid assets include US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. We obtain the data from the quarterly Reports of Condition and Income "Call Reports" (Form FFIEC 031) from 1984-2020.

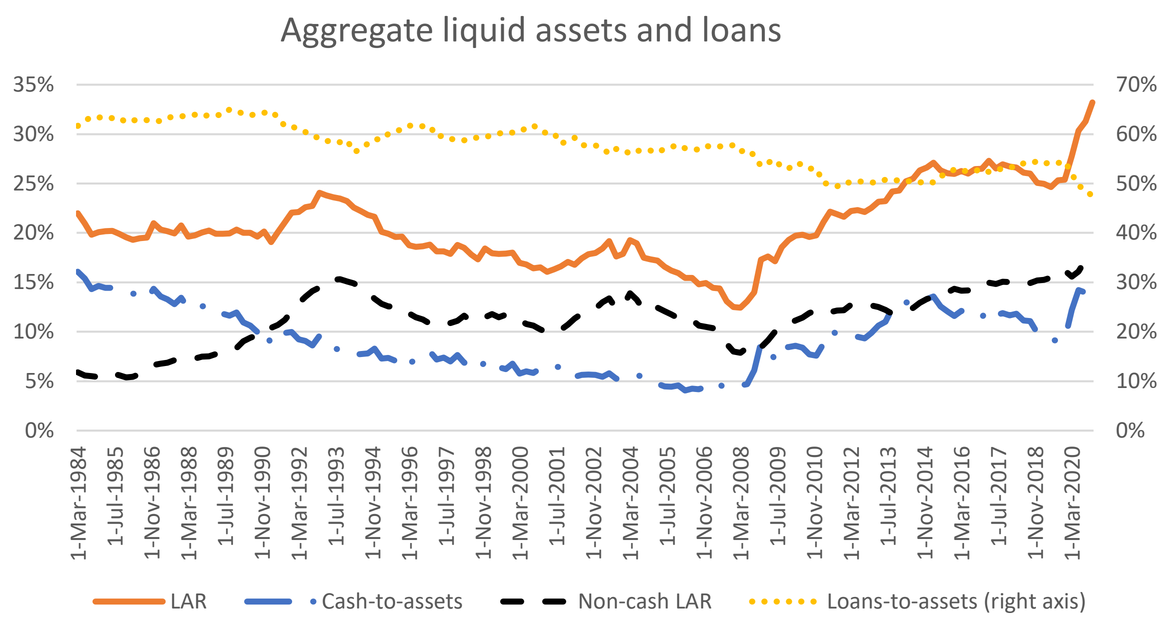


Figure 2. Average liquid asset ratio (LAR) by bank size

The figure shows the equally-weighted average liquid assets-to-assets ratio (LAR). The sample consists of US-chartered commercial banks with assets that exceed $2billion (in constant 2018 dollars). We define large banks to be banks with assets in excess of $50 billion dollars in 2018 dollars. Medium banks have assets between $10 billion and $50 billion. Small banks have assets between $2 billion and $10 billion. Liquid assets represent the sum of cash holdings and non-cash liquid assets. Cash holdings include vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks. Non-cash liquid assets include US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC. We obtain the data from the quarterly Reports of Condition and Income "Call Reports" (Form FFIEC 031) from 1984-2020.

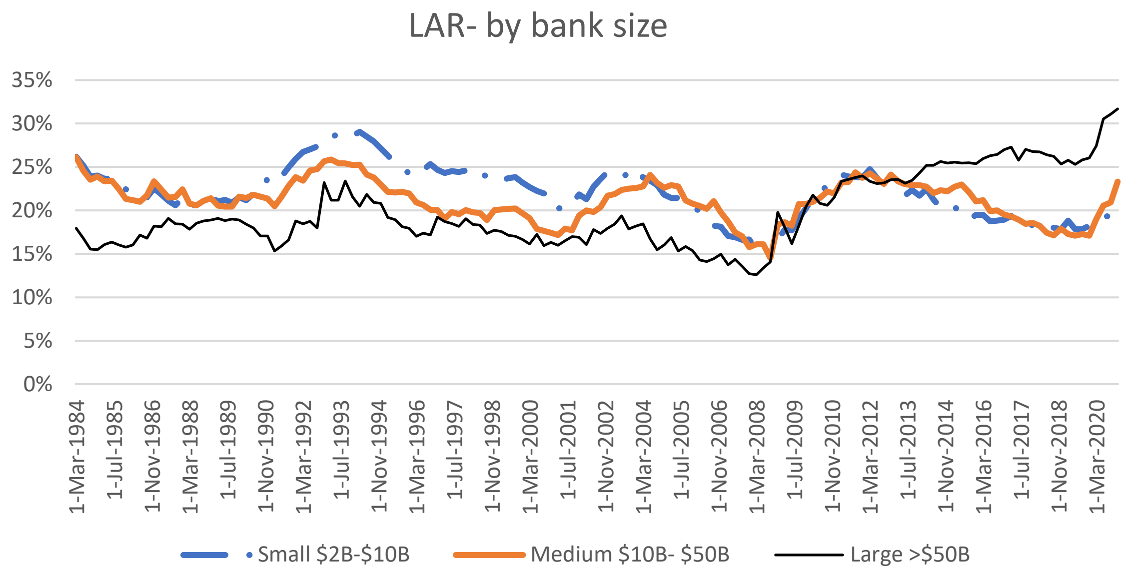
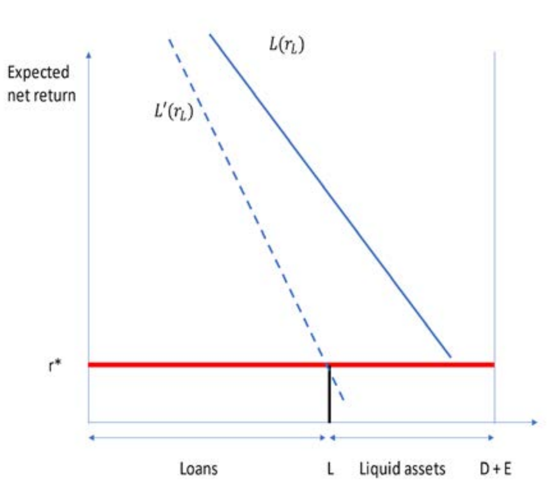


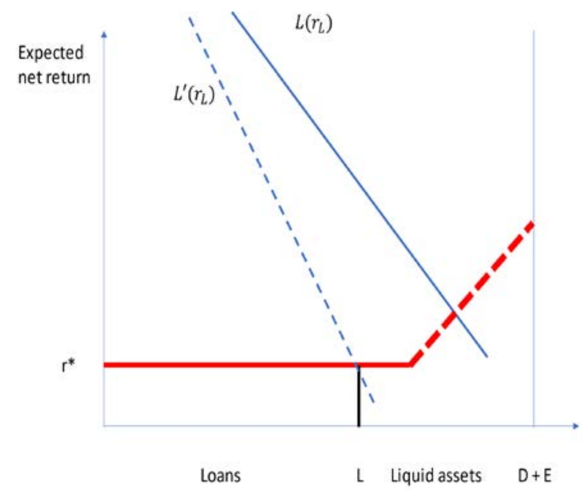
Figure 3. Equilibrium holdings of liquid assets

The size of the bank balance sheet is fixed at the sum of deposits (D) and equity (E). The market for loans is imperfectly competitive so that the demand for loans L(r_L) falls with the expected net return on loans r_{L}., i.e., L'(r_L) *< 0*. The bank sets the level of loans where the marginal revenue of loans, L'(r_L), equals the net expected return on liquid assets. The net expected return on liquid assets is equal to *r** when the marginal holdings of liquid assets have no risk management benefit, which is the continuous red line. The amount of loans is L. The amount of liquid assets is (D + E) – L. In Panel A, there is no risk management benefit of liquid assets. In Panel B, there is such a benefit. In Panel C, there is an exogenous increase in deposits. In Panel D, the liquidity requirement immobilizes an amount of liquid assets equal to (D+E) – LCR. Following the introduction of the LCR, the amount of liquid asset holdings increases from (D+E) – L to (D+E) – L*. The amount of loans falls from L to L*.

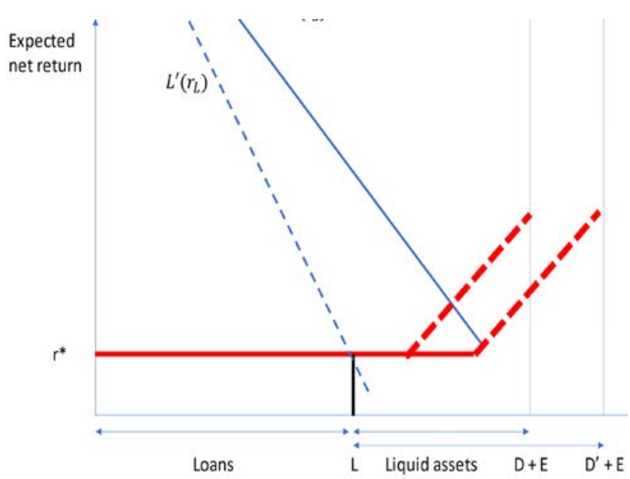
Panel A.



Panel B.



Panel C.



Panel D.

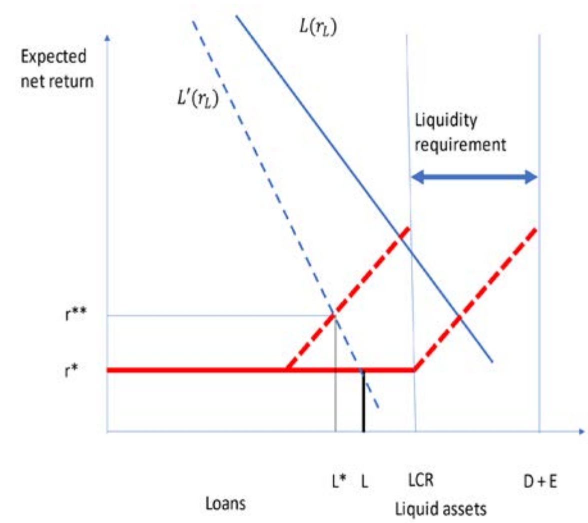
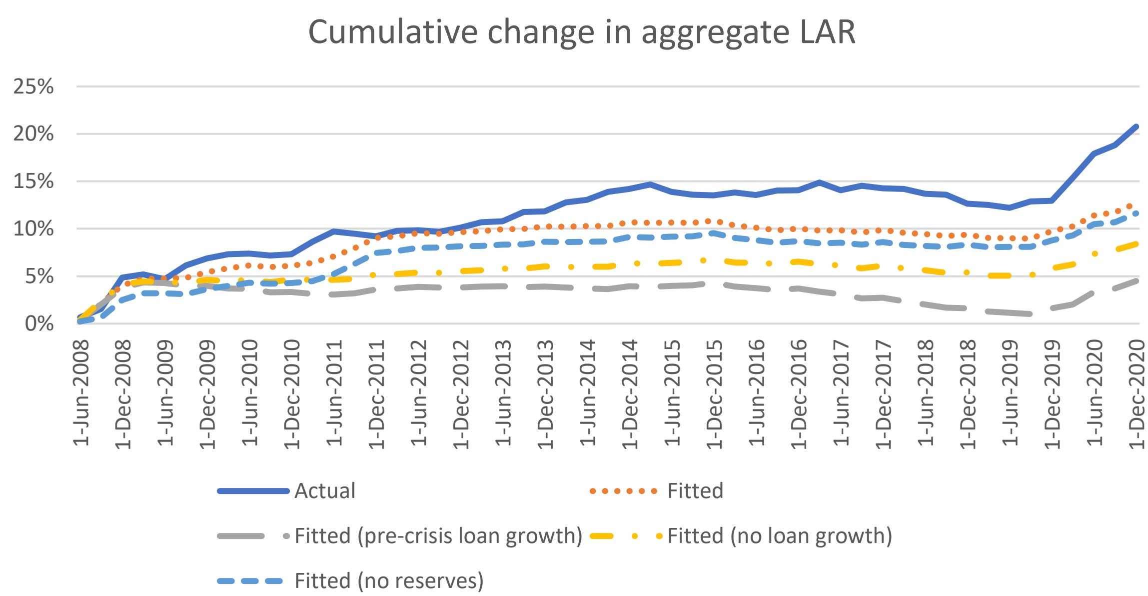


Figure 4. Evolution of aggregate liquid assets, loans, and deposits

Panel A shows the evolution of the cumulative change in aggregate liquid assets-to-assets ratio (LAR) since June 2008. Panel B shows the growth in aggregate loans and deposits during our sample period. Panel C shows the growth of aggregate liquid assets since June 2008. The aggregate LAR is computed by summing liquid assets for all banks in the sample and dividing by the sum of assets for all banks. Liquid assets represent the sum of cash holdings and non-cash liquid assets. Fitted values in Panel A (C) are the fitted values from the estimation of the model in Column (1) (Column (2)) of Table 4. Fitted values (pre-crisis loan growth) show what the fitted values would be if loans had grown at the same rate as for the ten years before the GFC (1996-2006). Fitted values-no loan growth (Fitted values-no reserves) are obtained from the estimation of the model in Column (1) of Table 4 that excludes Loan growth (Growth in aggregate reserves) as an explanatory variable.

Panel A.



Panel B.

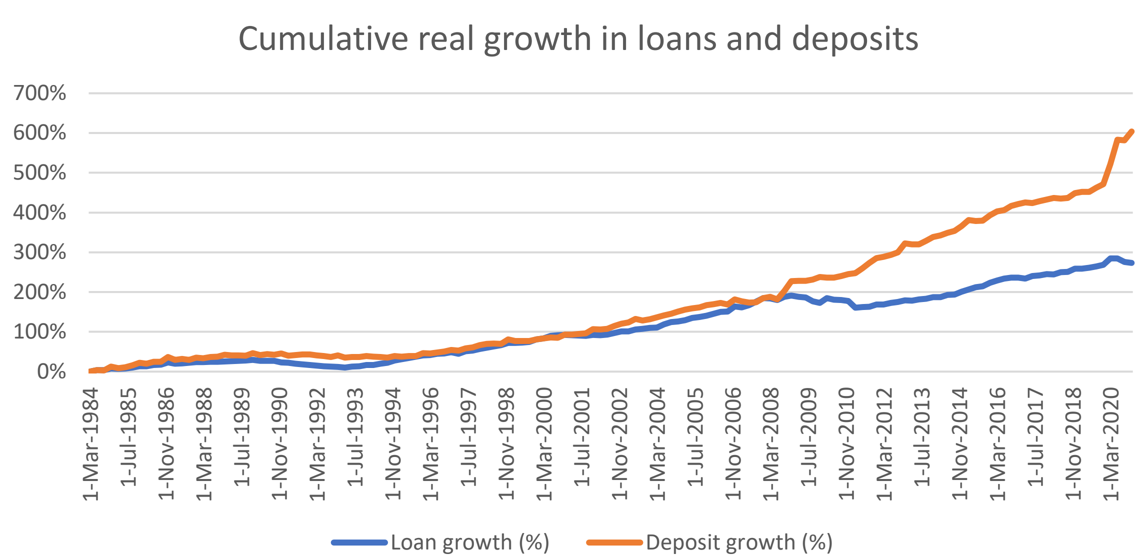
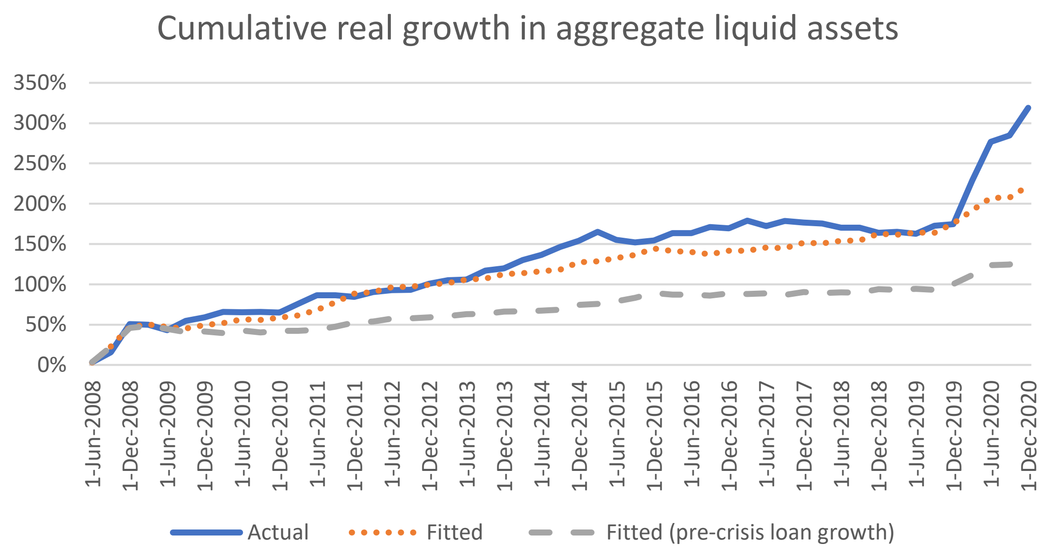


Figure 4. Evolution of aggregate liquid assets, loans, and deposits – continued

Panel C.



Appendix. Variable definitions

Variable name	Definition
Acquisitions-to-assets	Acquisition activity, scaled by assets. Source: COMPUSTAT.
Aggregate reserves	Total reserves of depository institutions (series TOTRESNS), scaled by total assets of commercial banks (TLAACBM027NBOG). Source: FRB St. Louis FRED database
Capex-to-assets	Capital expenditures, scaled by assets. Source: COMPUSTAT.
Cash holdings	Vault cash, cash items in the process of collection, balances due from depository institutions, and balances due from Federal Reserve Banks.
Cash flow-to-assets	Cash flow-to-assets. Cash flows is earnings after interest expense, taxes, and dividends, but before depreciation. For banks, it is computed as net income plus depreciation. Source: COMPUSTAT.
C&I loans-to-assets	Commercial and industrial loans divided by total assets.
Composite leading indicator	Amplitude adjusted Composite Leading Indicator, seasonally adjusted (series (USALOLITOAASTSAM). Source: FRB St. Louis FRED database.
Default spread	Difference between Moody's seasoned Baa bond yield (series BAA) and Aaa (series AAA) corporate bond yield. Source: FRB St. Louis FRED database.
Demand deposits-to-assets	Total demand deposits.
Deposits-to-assets	Total deposits divided by total assets.
Deposit volatility	The standard deviation of deposits-to-assets over the prior four quarters.
Derivatives	Total fair value of interest rate, equity, foreign exchange, and commodity derivate contracts held for trading, scaled by total assets.
Dividend payout	Indicator equal to one if a firm (bank) pays a common dividend in the year and zero otherwise. Source: COMPUSTAT.
Equity-to-assets	Total book value of equity divided by total assets.
Fed funds rate	The effective Federal Funds Rate (series FEDFUNDS). Source: FRB St. Louis FRED database.
Interest on excess reserves	The interest rate on excess reserves as determined by the Board of Governors (series IOER). Source: FRB St. Louis FRED database .
Large >$50B	Indicator variable for banks with assets greater than $50B (constant 2018 US$).
Large >$250B	Indicator variable for banks with assets greater than $250B that are subject to the Liquidity Coverage Ratio (LCR) rule.
Large public banks	Publicly traded banks with assets greater than $10 billion in constant 2018 US$. We classify banks as public if stock price data are available for the bank or for its bank holding company. For public multibank holding companies, a public bank is the largest entity in the holding company structure.
LAR	Total liquid assets, scaled by total assets. Liquid assets represent the sum of cash holdings, US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC.

Appendix. Variable definitions – continued

Variable name	Definition
Leverage	Long-term debt plus debt in current liabilities divided by book value of assets.
Loan growth	Average loan growth over the prior eight quarters.
Loans-to-assets	Loans divided by total assets.
Log (assets)	The natural logarithm of total assets ($000s).
Market-to-book	Book value of assets minus book value of equity plus market value of equity, scaled by the book value of assets. Source: CRSP/COMPUSTAT.
Net income-to-assets	Net income, scaled by total assets.
Non-cash liquid assets-to-assets	Non-cash liquid assets, scaled by total assets. Non-cash liquid assets represent the sum of US Treasuries, US government and government-sponsored agency obligations, and mortgage-backed securities issued or guaranteed by GNMA, FNMA, or FHLMC.
Non-deposit liabilities-to-assets	Non-deposit liabilities, scaled by total assets. Non-deposit liabilities equal total liabilities minus total deposits.
Other banks	All banks with assets between $2B and $50B (constant 2018 US$).
Other deposits-to-assets	Total deposits minus demand deposits, scaled by total assets.
Other securities-to-assets	Other securities, scaled by total assets. Other securities equal total securities minus liquid securities (non-cash liquid assets).
Personal loans-to-assets	Loans to individuals scaled by total assets.
RE loans-to-assets	Loans secured by real estate divided by total assets.
ROA volatility	The standard deviation of return on assets (ROA) over the prior four quarters.
Small	Indicator variable for banks with assets between $2B and $10B (constant 2018 US$).
T-bill rate	The 3-month Treasury bill rate (series TB3MS). Source: FRB St. Louis FRED database.
Trading assets	An indicator equal to one for banks with trading assets as of the prior quarter-end.
Tier 1 capital	Tier 1 capital, scaled by risk-weighted assets.
Commitments	Total unused commitments. The sum of unused commitments involving revolving open-end lines secured by 1-4 family residential properties, credit card lines, commitments to fund commercial real estate construction and development, securities underwriting, and other unused commitments.
US Treasuries	The sum of the amortized cost held-to-maturity US Treasury securities and the fair value of available for sale US Treasuries
Wholesale funding	The sum of large time deposits, deposits booked in foreign offices, subordinated debt and debentures, gross fed funds purchased, repos, and other borrowed money.